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NASA Technical Memorandum 109029

NONLINEAR RANDOM RESPONSE PREDICTION USING MSC/NASTRAN

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N94-17650

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G3/71 0194083

(NASA-TM-109029) NONLINEAR RANDOM RESPONSE PREDICTION USING MSC/NASTRAN (NASA) 62 p

OCTOBER 1993

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-0001

Abstract

An equivalent linearization technique has been incorporated into MSC/NASTRAN to predict the nonlinear random response of structures by means of Direct Matrix Abstract Programming (DMAP) modifications and inclusion of the nonlinear differential stiffness module inside the iteration loop. An iterative process was used to determine the rms displacements. Numerical results obtained for validation on simple plates and beams are in good agreement with existing solutions in both the linear and linearized regions. The versatility of the implementation will enable the analyst to determine the nonlinear random responses for complex structures under combined loads. The thermo-acoustic response of a hexagonal thermal protection system panel is used to highlight some of the features of the program.

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Section 1 Introduction

The current trends in advanced vehicle development show a need for lighter, more economical structural components. This trend, coupled with the increasing propulsion and environmental loads associated with these vehicles, has renewed interest in nonlinear structural response. This is most evident in, but not necessarily limited to, the aerospace industry with such proposed vehicles as the National Aero-Space Plane (NASP) and the High Speed Civil Transport (HSCT). Surface panels, particularly those exposed to the engine noise and jet exhaust and those in the region of shock boundary layer interactions, are anticipated to respond nonlinearily in at least part of the flight regime. Figure 1 depicts the thermo-acoustic loads on a single-stage-to-orbit vehicle. Other intense random loads may be transmitted through the structure from engine mounts or other hard points. To effectively and economically evaluate these structural components, a practical method of predicting their large deflection random response is required.

There are several methods currently in use to predict the large deflection random response of structures. A perturbation method [1] based on classical perturbation theory for nonlinear deterministic motion can be used to obtain approximate solutions to weakly nonlinear systems. A stochastic averaging method [2] yields approximate solutions when the damping is light and the excitation is broadband. This method has been applied principally to single-degree-of-freedom systems. The Fokker-Plank-Kolmogorov (FPK) approach [3] is the only method that yields an exact solution, but solutions are only available for a few restricted classes of problems. The numerical simulation technique, also referred to as the Monte Carlo method [4], is the most general method and yields the best results of all the approximate methods. A substantial drawback to the Monte Carlo method is the computational time required to solve realistic structural problems. The most widely used method is the equivalent linearization method [5]. It yields good approximate solutions for the statistics of the random response of simple and complex structures and lends itself to an incremental solution procedure similar to the methods employed in static nonlinear problems.

The equivalent linearization method for obtaining nonlinear random responses was an obvious choice for implementation in a commercial package. The technique has been used, refined, and validated by many authors [6—10]. The validation of the method is well documented by many authors for beams, plates, and other nonlinear dynamic structures. The refinements include methods for solving structural problems with thermal and acoustic loads, initial stresses, and imperfections. Techniques have been developed, for example, for the random response of pre- and post-thermally and mechanically buckled plates, linear and nonlinear statically deflected panels, and various combinations of concentrated and distributed random loads. The equivalent linearization procedure has been applied primarily in research or special purpose codes, so a general purpose finite element code incorporating this procedure was unavailable.

The MacNeal-Schwendler Corporation version of NASTRAN (MSC/NASTRAN) [11] was selected for this work due to its extensive use in the aerospace and automotive industries, where nonlinear random phenomena are most prevalent. The equivalent linearization

procedure was programmed as a "stand alone" solution sequence for version 67 using the Direct Matrix Abstraction Program (DMAP) [12] language. It was found that all the necessary components of the equivalent linearization procedure already existed as DMAP modules. The essence of the new solution sequence therefore consisted of incorporating the necessary modules and iterative procedures into an existing MSC/NASTRAN solution sequence for linear random analysis. Two solution sequences were available to serve as starting points: the Super Element Modal Frequency Response (SEMFREQ) and Super Element Direct Frequency Response (SEDFREQ) solution sequences. The SEMFREQ was chosen for reasons described in this report.

The large deflection finite element formulation is first reviewed to establish the general nonlinear equations of motion. The theory of equivalent linearization is then presented and the expression for the equivalent linear stiffness is derived. An overview of the iterative implementation of the equivalent linearization procedure is presented in flow chart form with consideration to the various methods of solving dynamic systems. The ease with which the expression for the equivalent linear stiffness is evaluated in multi-degree-of-freedom systems is somewhat dependent on the method used to form and solve the equations of motion. The evaluation of the equivalent linear stiffness and the particulars of programming the new solution sequence are presented for broad-band Gaussian loads and modal equations of motion. In the validation section of this report, textbook examples are used to compare the MSC/NASTRAN equivalent linearization solution sequence with published results. A series of simple plate problems are presented to show potential users how to use the solution sequences to solve a variety of problems. A final example problem is shown to demonstrate the ability of the solution sequence to efficiently solve complex structural problems.

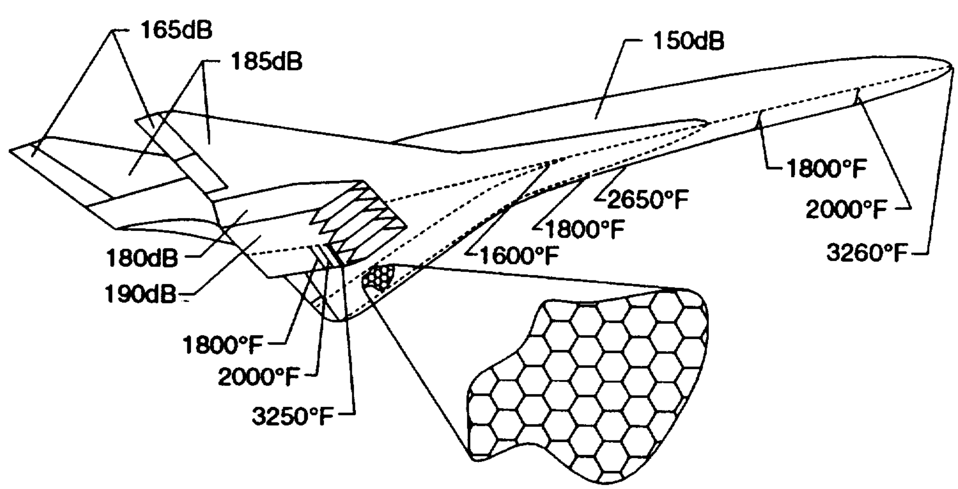

Figure 1: Design environment for a generic hypersonic vehicle

Section 2 Theory

The large deflection nonlinear finite element formulation is first reviewed for the determination of the system matrices. The equivalent linearization technique is then introduced for the solution of the nonlinear equations of motion. Several special cases are then considered for the determination of the equivalent linear stiffnesses.

2.1 Large Deflection Finite Element Formulation

The large deflection nonlinear strain-displacement relationships as taken from elasticity [13] are:

$$\begin{aligned}
\epsilon_x &= \frac{\partial u}{\partial x} + \frac{1}{2}\left[(\frac{\partial u}{\partial x})^2 + (\frac{\partial v}{\partial x})^2 + (\frac{\partial w}{\partial x})^2\right] \\
\epsilon_y &= \frac{\partial v}{\partial y} + \frac{1}{2}\left[(\frac{\partial u}{\partial y})^2 + (\frac{\partial v}{\partial y})^2 + (\frac{\partial w}{\partial y})^2\right] \\
\epsilon_z &= \frac{\partial w}{\partial z} + \frac{1}{2}\left[(\frac{\partial u}{\partial z})^2 + (\frac{\partial v}{\partial z})^2 + (\frac{\partial w}{\partial z})^2\right] \\
\gamma_{xy} &= \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} + \left(\frac{\partial u}{\partial x}\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\frac{\partial v}{\partial y} + \frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right) \\
\gamma_{xz} &= \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} + \left(\frac{\partial u}{\partial x}\frac{\partial u}{\partial z} + \frac{\partial v}{\partial x}\frac{\partial v}{\partial z} + \frac{\partial w}{\partial x}\frac{\partial w}{\partial z}\right) \\
\gamma_{yz} &= \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y} + \left(\frac{\partial u}{\partial y}\frac{\partial u}{\partial z} + \frac{\partial v}{\partial y}\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\frac{\partial w}{\partial z}\right)
\end{aligned} \tag{1}$$

where u, v, and w are the three displacements, ϵ_x, ϵ_y, and ϵ_z are the normal strains, and γ_{xy}, γ_{xz}, and γ_{yz} are the shear strains. All are functions of x, y, and z.

For an arbitrary finite element, assume nondimensional shape functions, N_n, such that

$$u(x,y,z) = \{N_1 \;\; N_2 \;\; \cdots \;\; N_n\}\begin{Bmatrix} u_1 \\ u_2 \\ \vdots \\ u_n \end{Bmatrix} \tag{2}$$

$$v(x,y,z) = \{N_1 \;\; N_2 \;\; \cdots \;\; N_n\}\begin{Bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{Bmatrix} \tag{3}$$

$$w(x,y,z) = \{N_1 \; N_2 \; \cdots \; N_n\} \begin{Bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{Bmatrix} \tag{4}$$

where $\{u_1 \; u_2 \; \cdots \; u_n\}$, $\{v_1 \; v_2 \; \cdots \; v_n\}$, and $\{w_1 \; w_2 \; \cdots \; w_n\}$ are the vectors of nodal displacements for the n nodes of the element.

The matrix form of equation (1) is [14]

$$\begin{aligned} \{\varepsilon\} &= \{\varepsilon_L\} + \{\varepsilon_N\} \\ &= [H_L]\{q\} + \frac{1}{2}[H]\{\theta\} \end{aligned} \tag{5}$$

where

$$\begin{aligned} \{\varepsilon\} &= \{\varepsilon_x \; \varepsilon_y \; \varepsilon_z \; \gamma_{xy} \; \gamma_{xz} \; \gamma_{yz}\}^T \\ \{q\} &= \{u_1 \; v_1 \; w_1 \; \cdots \; u_n \; v_n \; w_n\}^T \\ \{\theta\} &= \{u_{,x} \; v_{,x} \; w_{,x} \; u_{,y} \; v_{,y} \; w_{,y} \; u_{,z} \; v_{,z} \; w_{,z}\}^T \end{aligned} \tag{6}$$

The subscripts L and N denote the linear and nonlinear part of the total strain, respectively, and superscript T denotes transpose of a quantity.

The variation of the strain, $\{\varepsilon\}$, is expressed as

$$\begin{aligned} \{\delta\varepsilon\} &= \{\delta\varepsilon_L\} + \{\delta\varepsilon_N\} \\ &= [H_L]\{\delta q\} + \frac{1}{2}([\delta H]\{\theta\} + [H]\{\delta\theta\}) \\ &= [H_L]\{\delta q\} + [H][G]\{\delta q\} \\ &= [B]\{\delta q\} \end{aligned} \tag{7}$$

where the matrices $[H_L]$, $[H]$, $\{\theta\}$, and $[G]$ in equations (5) and (7) are

$$[H_L] = \begin{bmatrix} \frac{\partial N_1}{\partial x} & 0 & 0 & \frac{\partial N_2}{\partial x} & 0 & 0 & & \frac{\partial N_n}{\partial x} & 0 & 0 \\ 0 & \frac{\partial N_1}{\partial y} & 0 & 0 & \frac{\partial N_2}{\partial y} & 0 & & 0 & \frac{\partial N_n}{\partial y} & 0 \\ 0 & 0 & \frac{\partial N_1}{\partial z} & 0 & 0 & \frac{\partial N_2}{\partial z} & \cdots\cdots & 0 & 0 & \frac{\partial N_n}{\partial z} \\ \frac{\partial N_1}{\partial y} & \frac{\partial N_1}{\partial x} & 0 & \frac{\partial N_2}{\partial y} & \frac{\partial N_2}{\partial x} & 0 & & \frac{\partial N_n}{\partial y} & \frac{\partial N_n}{\partial x} & 0 \\ \frac{\partial N_1}{\partial z} & 0 & \frac{\partial N_1}{\partial x} & \frac{\partial N_2}{\partial z} & 0 & \frac{\partial N_2}{\partial x} & & \frac{\partial N_n}{\partial z} & 0 & \frac{\partial N_n}{\partial x} \\ 0 & \frac{\partial N_1}{\partial z} & \frac{\partial N_1}{\partial y} & 0 & \frac{\partial N_2}{\partial z} & \frac{\partial N_2}{\partial y} & & 0 & \frac{\partial N_n}{\partial z} & \frac{\partial N_n}{\partial y} \end{bmatrix} \tag{8}$$

$$[H] = \begin{bmatrix} a_x^T & 0 & 0 \\ 0 & a_y^T & 0 \\ 0 & 0 & a_z^T \\ a_y^T & a_x^T & 0 \\ 0 & a_z^T & a_y^T \\ a_z^T & 0 & a_x^T \end{bmatrix} \tag{9}$$

with

$$\{a_i\} = \left\{ \begin{array}{c} \frac{\partial u}{\partial i} \\ \frac{\partial v}{\partial i} \\ \frac{\partial w}{\partial i} \end{array} \right\} = [\ \frac{\partial N_1}{\partial i} I \quad \frac{\partial N_2}{\partial i} I \quad \cdots \quad \frac{\partial N_n}{\partial i} I\ ]\{q\} \qquad i = x, y, z \tag{10}$$

$$\{\theta\} = \left\{ \begin{array}{c} u_{,x} \\ v_{,x} \\ w_{,x} \\ u_{,y} \\ v_{,y} \\ w_{,y} \\ u_{,z} \\ v_{,z} \\ w_{,z} \end{array} \right\} = \begin{bmatrix} \frac{\partial N_1}{\partial x} I & \frac{\partial N_2}{\partial x} I & \cdots & \frac{\partial N_n}{\partial x} I \\ \frac{\partial N_1}{\partial y} I & \frac{\partial N_2}{\partial y} I & \cdots & \frac{\partial N_n}{\partial y} I \\ \frac{\partial N_1}{\partial z} I & \frac{\partial N_2}{\partial z} I & \cdots & \frac{\partial N_n}{\partial z} I \end{bmatrix} \left\{ \begin{array}{c} u_1 \\ v_1 \\ w_1 \\ u_2 \\ v_2 \\ w_2 \\ \vdots \\ u_n \\ v_n \\ w_n \end{array} \right\} = [G]\{q\} \tag{11}$$

The matrix [I] in equations (10) and (11) is a (3×3) identity matrix and the vector {q} is the vector of nodal displacements. Note that the shape function and displacement vector are dependent on the particular element chosen.

The internal force is computed from the equation of static equilibrium,

$$F = \int_V [B]^T \{\sigma\} \, dV \tag{12}$$

and the variation of the internal force is

$$\delta F = \int_V [B]^T \{\delta\sigma\} \, dV + \int_V [\delta B]^T \{\sigma\} \, dV \tag{13}$$

Substituting equation (5) and the stress-strain relation,

$$\{\delta\sigma\} = [D]\{\delta\varepsilon\} \tag{14}$$

into equation (13) and using the identity,

$$\begin{aligned} \{\delta B\}^T \{\sigma\} &= [G]^T [\delta H]^T \{\sigma\} \\ &= [G]^T [\tau] \{\delta\theta\} \\ &= [G]^T [\tau][G]\{\delta q\} \end{aligned} \tag{15}$$

yields a simple expression for the variation of internal force.

$$\delta F = \left[k + k1\{q\} + k2\{q\}\{q\}^T \right] \{\delta q\} \tag{16}$$

The quantities k, $k1\{q\}$, and $k2\{q\}\{q\}^T$ in equation (16) are given as

$$[k] = \int_V [H_L]^T [D][H_L] \, dV + [k_g] \tag{17}$$

$$k1\{q\} = \int_V ([H_L]^T[D][H][G] + [G]^T[H]^T[D][H_L])\, dV \tag{18}$$

$$k2\{q\}\{q\}^T = \int_V [G]^T[H]^T[D][H][G]\, dV \tag{19}$$

with

$$[k_g] = \int_V [G]^T[\tau][G]\, dV \tag{20}$$

$$[\tau] = \begin{bmatrix} \sigma_x I & \tau_{xy} I & \tau_{xz} I \\ \tau_{yx} I & \sigma_y I & \tau_{yz} I \\ \tau_{zx} I & \tau_{zy} I & \sigma_z I \end{bmatrix} \tag{21}$$

In equations (17 — 19), [D] is the material property matrix, [k] is the linear stiffness matrix, k1 and k2 are the nonlinear stiffnesses, and $[k_g]$ is the geometric stiffness (which depends on the initial stresses).

The element internal force vector $\{\gamma\}$ is defined as

$$\{\gamma\} = \Big[[k] + [k1\{q\}] + \big[k2\{q\}\{q\}^T\big]\Big]\{q\} \tag{22}$$

and the system internal force $\{\Gamma\}$ is

$$\{\Gamma\} = \Big[[K] + [K1\{Q\}] + \big[K2\{Q\}\{Q\}^T\big]\Big]\{Q\} \tag{23}$$

The system mass and damping matrices are obtained using the standard finite element formulation [15].

The equation of motion based on the nonlinear strain-displacement relations is

$$[M]\{\ddot{Q}\} + [C]\{\dot{Q}\} + \Big[[K] + [K1\{Q\}] + \big[K2\{Q\}\{Q\}^T\big]\Big]\{Q\} = \{P\} \tag{24}$$

or, in more general form, as

$$[M]\Big\{\ddot{Q}\Big\} + [C]\Big\{\dot{Q}\Big\} + \{\Gamma(Q, Q^2, Q^3)\} = \{P\} \tag{25}$$

where the matrices [M], [C], and [K] are the system linear mass, damping, and stiffness matrices. The vector {P} is the time dependent load and K1 and K2 are the system first- and second-order nonlinear stiffnesses.

Equation (25) has no general solution when the excitation is random. An approximate solution to these equations is obtained by seeking an equivalent linear system [6], of the form

$$[M]\{\ddot{Q}\} + [C]\{\dot{Q}\} + [K_e]\{Q\} = \{P\} \tag{26}$$

where $[K_e]$ is an equivalent linear stiffness matrix.

2.2 Equivalent Linear Stiffness Matrix $[K_e]$

The equivalent linear stiffness matrix $[K_e]$ is to be determined such that the difference between the actual nonlinear system and the approximate linear system is minimized. The approach may be thought of as a statistical version of a classical least square minimization. The error in obtaining the approximate system is defined as

$$\{\Delta\} = \{\Gamma\} - [K_e]\{Q\} \tag{27}$$

Since the error is a random function of time, the required condition is that the ensemble average or expectation of the mean square error be a minimum. This is expressed as

$$E\left[\{\Delta\}\{\Delta\}^T\right] \rightarrow \text{minimum} \tag{28}$$

where $E[\cdot]$ denotes the expectation operator. As in the cases of classical least square minimization, the necessary condition for satisfying equation (28) is

$$\frac{\partial E\left[\{\Delta\}\{\Delta\}^T\right]}{\partial [K_e]} = 0 \tag{29}$$

Substituting equation (27) into equation (29), and interchanging the expectation and differentiation operators yields

$$E\left[\{\Gamma\}\{Q\}^T\right] = E\left[\{Q\}\{Q\}^T\right][K_e]^T \tag{30}$$

Using the fact that the matrix $E[\{Q\}\{Q\}^T]$ is non-singular, the equivalent linear stiffness matrix $[K_e]$ can be determined from the equation

$$[K_e] = E\left[\{Q\}\{Q\}^T\right]^{-1} E\left[\{\Gamma\}\{Q\}^T\right] \tag{31}$$

The equivalent linear stiffness $[K_e]$ defined in equation (31) can be directly programmed in a finite element code if the stiffnesses K1 and K2 are available and the expectation operator can be evaluated.

Two assumptions regarding the distribution and dependance of the displacements are necessary in order to evaluate equation (31). The most commonly assumed distribution of the displacements is a Gaussian distribution, since the most commonly encountered random loads are typically modelled by Gaussian distributions. The most commonly assumed dependence between displacement responses is that they are independent. This is simply because, in a linear modal analysis, the modal responses are solved for independently; their modes are uncoupled. These assumptions are not the only possible assumptions; other assumptions can easily be substituted, but would yield more complicated results.

It is generally assumed that the response is Gaussian if the load is Gaussian. By using the formula for the expected value of a Gaussian vector $\{\eta\}$

$$E[f(\eta)\,\eta] = E\left\{\eta\,\eta^T\right\} E\{\nabla f(\eta)\} \tag{32}$$

where ∇ is the gradient operator, $E[\{\Gamma\}\{Q\}^T]$ on the right hand side of equation (31) becomes

$$E\left[\{Q\}\{Q\}^T\right] E\left[\frac{\partial \Gamma}{\partial Q}\right] \tag{33}$$

or

$$E\left[\{Q\}\{Q\}^T\right] E\left[\frac{\partial\left[\left[[K] + [K1\{Q\}] + \left[K2\{Q\}\{Q\}^T\right]\right]\{Q\}\right]}{\partial\{Q\}}\right] \tag{34}$$

. The equivalent linear stiffness matrix $[K_e]$ can then be determined from the equation

$$[K_e]= E\left[\frac{\partial \Gamma}{\partial Q}\right] = E\left[\frac{\partial\left[\left[[K] + [K1\{Q\}] + \left[K2\{Q\}\{Q\}^T\right]\right]\{Q\}\right]}{\partial\{Q\}}\right] \tag{35}$$

where $[K_e]$ is an equivalent linear function of the displacement vector $\{Q\}$, which is one order less than the nonlinear system stiffness matrix $\{\Gamma\}$.

The nonlinear stiffnesses are generally formed in tangential or differential form and the expectation operator in equation (35) requires knowledge of the joint probability density function of the response vector, which is the unknown. Therefore, the equivalent linearization solution procedure is programmed in an iterative fashion and some additional assumptions regarding the expectations of the response vector are required. It should be noted that, if K1 and K2 are available, the mean square response can be obtained directly [7] with appropriate assumptions for the expectation operator.

In all instances cited above, assumptions regarding the expectations of the response vector are required. These assumptions are usually based on a knowledge of the excitation and the solution method used. A discussion of the general iterative equivalent linear solution procedures is next presented.

2.3 Iterative Equivalent Linearization Solution Methods

There are two basic means to solve linear dynamic equations of motion: one uses the physical degrees of freedom and the other uses the modal degrees of freedom. The first method is generally referred to as the direct frequency response method and requires solving a complex coupled system of equations in the nodal degrees of freedom at each frequency of interest. The second method is generally referred to as the modal frequency response method. It involves solving for the linear eigenvectors first and transforming the equations of motion into modal coordinates. The resulting system of equations is uncoupled and can be easily solved at each frequency of interest.

The primary consideration as to which method to use for a particular linear system is based on the computational time required. This decision in an equivalent linearization solution procedure is further complicated by the iterative nature of the problem and the evaluation of the expectations. The choice of method can either greatly simplify or complicate the process.

The direct method would seem to be the easiest and most straightforward to implement, and the computational time required would be simple to compute. The difficulty in the direct method arises in the assumptions regarding the expectation operator in the expression for the equivalent linear stiffness and the implementation of these assumptions in a general sense. Accurate approximations of the expectation operator require assumptions regarding the full set of four moments (mean, standard deviation, skewness, and kurtosis) of the response vector in nodal degrees of freedom. It should be noted that in physical coordinates, the correlations between all the degrees of freedom are necessary and must be determined.

As a simple example of the direct method, consider a beam of length L with ten nodes and three degrees of freedom, u, w, and θ, at each node. The evaluation of equation (31) for the equivalent linear stiffness requires the evaluation of the complete set of expectations of all the nodal degrees of freedom to the fourth moments. The equivalent linearization solution relies on determining expressions for the third and fourth moments in terms of the first and second moments. These may be obtained by assuming appropriate probability distributions for the nodal displacements. In the beam example, if the excitation is broadband, Gaussian distributed, and spatially correlated over the beam, it can be assumed that the responses w and θ are Gaussian and u is Chi-square distributed. From these assumptions, an expression for the equivalent linear stiffness in terms of the first and second moments of the response can be found. However each entry in the 30×30 equivalent linear stiffness matrix could have a different coefficient representative of the degrees of freedom, correlation coefficients between the degrees of freedom, and the order of the expectations involved. The complexity in using physical degrees of freedom can be deduced from this simple problem when it is noted that it is terms such as the square of the slope and the in-plane displacement that are strongly correlated. This entire process is programmable, but it is not easily done in a general sense. The selection of modal coordinates will be seen to make the evaluation of equation (31) simpler.

The modal solution method of the equivalent linearization procedure is simpler to implement than the direct method because reasonable assumptions regarding the correlation of the modal degrees-of-freedom as well as their joint distribution are possible. This is not to say that the modal approach is without deficiencies or difficulties. To illustrate the advantages and difficulties with the iterative modal solution procedure, the simple beam problem discussed in the direct method is used. The first difficulty arises immediately from the linear eigenvalue problem. The extracted eigenvectors are functions of either the out-of-plane nodal displacement (bending modes) or the in-plane nodal displacement (membrane modes), but not both. This is because the bending motion of the beam is coupled to the membrane motion through the nonlinear terms.

There are three ways to handle the decoupling of the membrane and bending motion induced by the use of the linear eigenvectors. The first way is to simply exclude the membrane modes from the modal response. This is easy, but not particularly accurate. A popular corollary to this solution is used for one- and two-dimensional structures [7]. This procedure assumes the in-plane inertia and damping to be negligible. It is then possible to solve for the membrane modes in terms of the bending modes and thus account for the

in-plane stiffness. This procedure is efficient, but highly specialized and difficult to include in a general finite element code.

The second method involves selecting particular bending modes and membrane modes to include in the formulation. The difficulties that arise from this solution are similar to those encountered in the direct method when trying to evaluate the expectations and solving the system of equations. In the beam problem, it is again assumed that the bending is Gaussian and the membrane is Chi-square distributed when the excitation is Gaussian. The bending modes can be assumed uncorrelated with respect to each other, as can be the membrane modes, but the membrane modes are strongly correlated to the square of the bending modes. The resulting system of equations is coupled and the expression for the equivalent linear stiffness matrix is only marginally simplified with respect to the direct method. Another difficulty with the linear modal solution procedure is that the type of modes, bending, membrane, or otherwise, are not always readily identifiable or available. Many current finite element programs use Lanczos-type eigenvalue solvers in which only the lowest modes or modes within a certain range are computed. It is difficult to construct a general program using this method that will extract the particular eigenvectors needed for an accurate solution.

The third modal solution method for the equivalent linearization procedure uses updated or "equivalent linear" modes. The obvious drawback to this method is that it requires the eigenvalue problem to be solved at each iteration. The advantages of this method are that the system of equations that are solved at each frequency are uncoupled and that simple assumptions regarding the moments and correlation of the modal responses are adequate for accurate solutions. The simple beam problem discussed in the previous solution methods could be solved with only a small number of updated modes. If the load were Gaussian, these modes could be assumed Gaussian-distributed and uncorrelated. Although the means of the equivalent linear modal amplitudes are also assumed to be zero, this does not require that all the nodal displacements comprising the mode shape have zero means. The relationship between the mean of the in-plane displacement, u, and the mean square of the slopes, θ, in the simple beam problem, is implicitly maintained in the equivalent linear modal approach.

The relationship between the steps involved in the direct, linear modal, and equivalent linear modal approaches to implementing the equivalent linearization solution procedure are outlined in the flowchart in figure 2 for a general finite element program. The solution procedure is iterative as previously discussed, since the nonlinear stiffness is only available in a differential form. The convergence of the iterative procedure is based on the Euclidian norm of the response variance vector. It was determined that the equivalent linear modal method of solving the iterative equivalent linearization procedure would be the simplest and most versatile of the three methods to implement in MSC/NASTRAN.

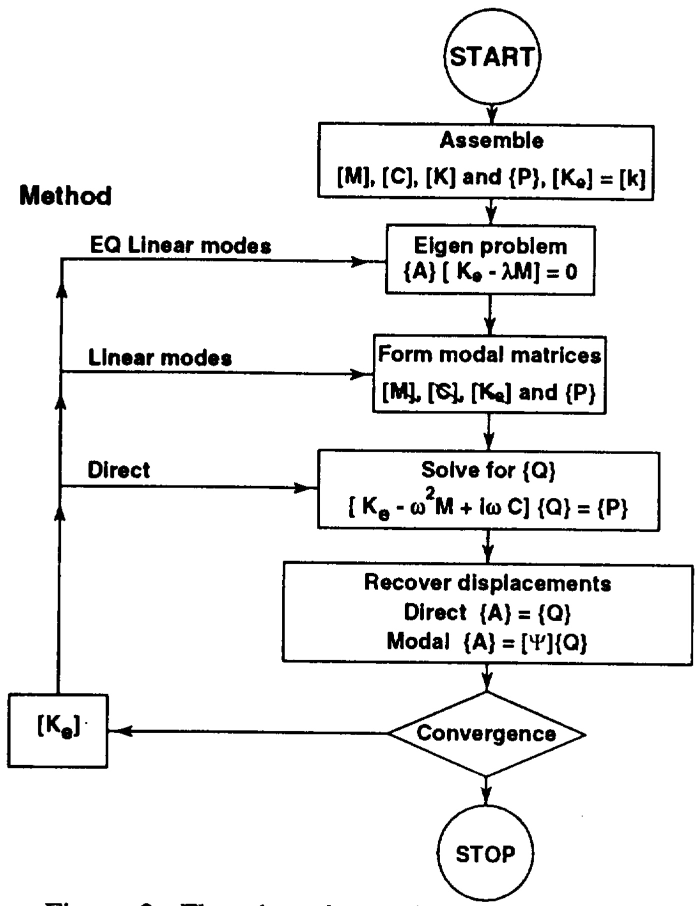

Figure 2: Flowchart for equivalent linearization solution procedure

2.4 Implementation

The equivalent linear stiffness matrix in equation (31) must first be expressed in equivalent linear modal coordinates in order to evaluate the expectation operator. The stiffness vector $\{\Gamma(Q, Q^2, Q^3)\}$ in equivalent linear modal coordinates has the form $\{\overline{\Gamma}(A, A^3)\}$, where the bar indicates a quantity transformed in modal coordinates. The expression for the equivalent linear stiffness, equation (35), with the Gaussian, zero mean, and uncorrelated modal response assumptions reduces to

$$\left[\overline{K_e}\right] = E\left[\frac{\partial\{\overline{\Gamma}\}}{\partial\{A\}}\right] \tag{36}$$

The partial derivatives are easily performed and yield a linear modal stiffness matrix and a differential modal stiffness matrix that is based on the mean square of the modal response [5]. The modal representation of the equivalent linear stiffness is then

$$\left[\overline{K_e}\right] = \left[\overline{K}\right] + 3\left[\overline{K2}(E[A^2])\right] \tag{37}$$

This model expression is not directly programmable in MSC/NASTRAN. It must instead be expressed in physical coordinates, since the eigenvalue problem in MSC/NASTRAN is solved in physical coordinates. In addition, the differential stiffness matrix in MSC/NASTRAN is formed using the physical displacements. The linear stiffness matrix in equation (35) in physical coordinates is simply the linear stiffness matrix as assembled and computed in the MSC/NASTRAN program. The differential stiffness matrix expression in physical coordinate is the MSC/NASTRAN differential stiffness matrix formed using an equivalent linear displacement vector. This equivalent linear displacement vector is given by

$$\{Q\} = [\overline{\Phi}]\{\sigma_A\} + [\overline{\Phi}]\{\mu_o\} \tag{38}$$

where $\{\sigma_A\}$ is a vector of the standard deviations of the equivalent linear modal amplitudes and $[\overline{\Phi}]$ is the matrix of normalized eigenvectors. The standard deviation of the modal amplitudes is always positive. The sign convention of the physical displacement is determined by the eigenvectors. The vector $\{\mu_o\}$ is the mean displacement obtained from a static solution sequence. The matrix of eigenvectors is normalized such that the magnitude of each eigenvector in the matrix is unity. The final expression for the equivalent linear stiffness is then

$$[K_e] = [K] + 3[K_R] \tag{39}$$

where $[K_R]$ is the standard MSC/NASTRAN differential stiffness matrix.

Section 3 Programmer's Notes

The MSC/NASTRAN version 67 solution sequences are written using a common set of "subroutines" or SUBDMAPs. It is the MAIN SUBDMAPs, "main programs," that vary significantly and usually contain the essence of the solution procedure. The authors attempted to follow this structure in the development of the new Super Element Modal Equivalent Linear Random Response (SEMELRR) solution sequence, but some alterations to the common SUBDMAPs were also necessary. These alterations to the SUBDMAPs, as well as a description of the MAIN SUBDMAP of the SEMELRR solution sequence, are outlined.

All solution sequences are broken down into three general sections. These sections are simply expressed as Phase 1, Phase 2, and Phase 3. The Phase 1 portion of the program is dedicated primarily to the setting-up of the problem and the assembly of the linear matrices. Key portions of these procedures are the reading of the NASTRAN data deck, the restart capability, the creation of the element summary tables, the partitioning of the global degrees of freedom into the various analysis set tables (USET, etc.), and the formation and assembly of the linear elements and their reduction to the analysis set. The Phase 2 procedures are primarily associated with the actual solution of the problem. These solution procedures are, for example, the eigenvalue and eigenvector extraction routine of SOL 103, the linear matrix equation solvers in SOL 101, and the modal matrix formation and complex frequency response solver routines in SOL 111. SOL 106, the nonlinear static solution sequence, has a complicated Phase 2. This Phase 2 involves an iterative solution procedure similar to the solution sequence that was written into the Phase 2 of the SEMELRR solution sequence. Phase 3 procedures are primarily associated with post-processing routines such as data recovery, plotting and printing, and stress/strain calculations. Phase 3 also includes the dynamic sensitivity analysis. The calculation of power spectral densities and root mean square responses for random analysis using SOL 111 and SOL 108 are also included in Phase 3 procedures. The scattered placement of these procedures caused difficulty in the implementation of the equivalent linearization solution procedure.

3.1 SEMELRR Main SUBDMAP

As a starting point from which to write the SEMELRR DMAP, the authors selected the MSC/NASTRAN-delivered SOL 111 main SUBDMAP. This solution sequence is capable of performing linear random analysis. The primary additions to this solution sequence were envisioned to be the incorporation of Phase 2 procedures, similar to those found in SOL 106, for the formation of the nonlinear stiffness matrices and the iterative solution method. It was immediately apparent that the logical flow of the set of MSC/NASTRAN SUBDMAPs and modules did not readily permit simultaneous geometric nonlinearities and dynamics. The SEMELRR Solution sequence would have to be a hybrid-type solution sequence comprised of linear and nonlinear Phases. The calculation of the rms quantities, which usually occurs in Phase 3, and the necessity of having that information available in the iterative procedures required the new solution sequence to have no clear distinction between Phase 2 and Phase 3.

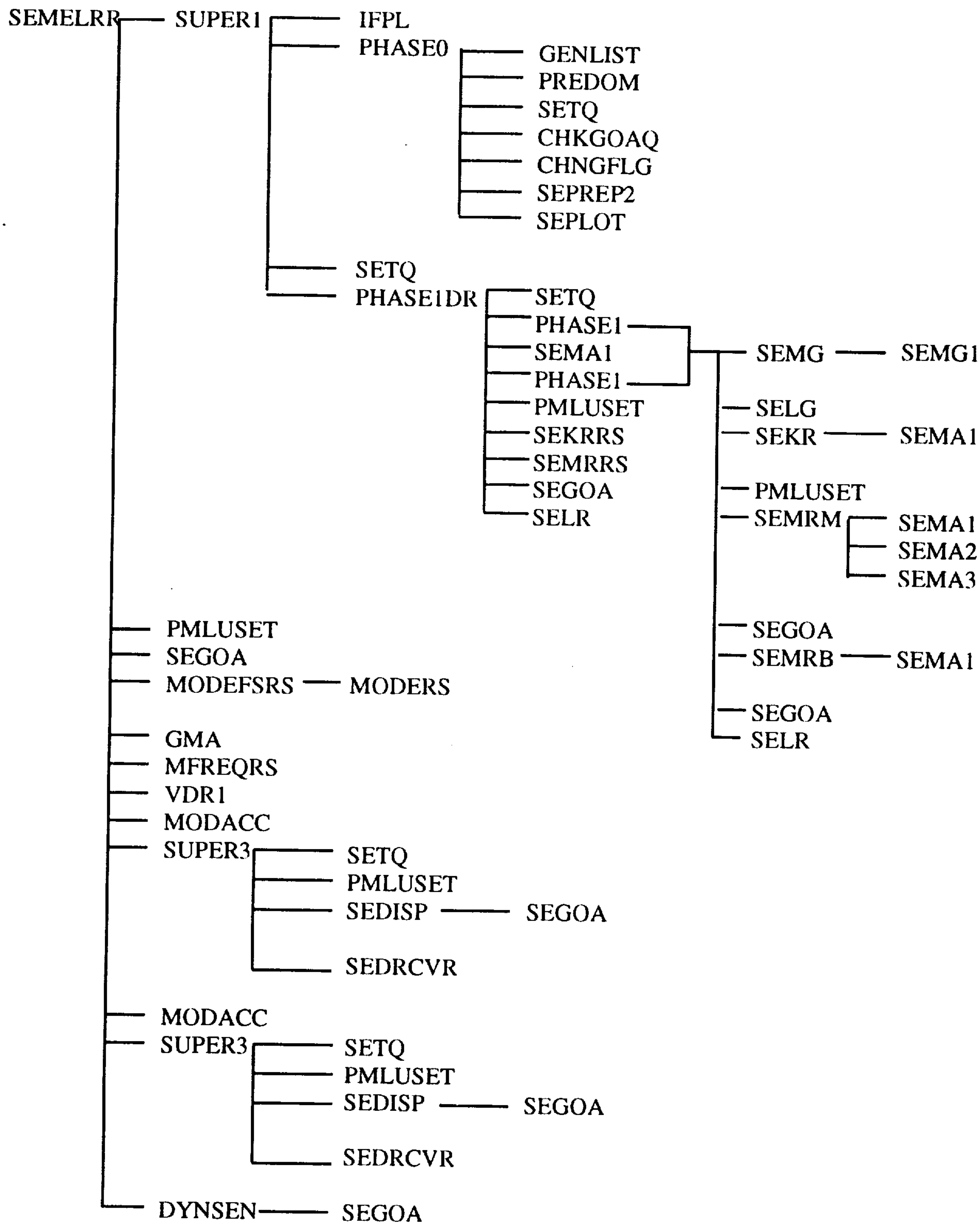

Figure 3: SUBDMAP call tree of SEMELRR solution sequence

The logical flow of MSC/NASTRAN solution sequences is partly controlled by parameters and flags that are set in the main SUBDMAP of the solution sequence. These flags are passed to the standard SUBDMAPs and appear in IF, THEN, ELSE type logical construction. Typical character parameters are the solution type (SOLTYP= "DIRECT," "MODAL," etc.), solution approach (APP= "STATIC," "FREQRESP," "TRANRESP," etc.), and logical flags are (NONLNR, AERO, FS, etc.). The logical flow for a nonlinear dynamic solution sequence does not exist, but by changing these parameters during the solution procedure the necessary logical flow can be generated.

The SEMELRR solution sequence requires that linear and nonlinear element tables be generated in Phase 1 procedures and that linear dynamic data recovery be performed in Phase 3 procedures. In order to generate the necessary matrices and tables for both geometric nonlinear and linear dynamic procedures, the pre-processing sequence Phase 1 was initiated with the NONLNR flag set to TRUE in the call to SUPER1, Figure 3, and the APP (approach) was set to FREQRESP. The reader is referred to the MSC/NASTRAN user's manual [11] for a description of these parameters.

The logical flag NONLNR was set TRUE for Phase 1 only, in the call to SUPER1, and not for Phase 2 or 3, because linear data recovery is required in SUPER3. In addition to this modification, it was required that the element summary table, ESTL, needed for linear dynamic analysis (not generated when NONLNR is TRUE) be equivalenced to the element summary table, EST, for the linear portion of nonlinear analysis (generated when NONLNR is TRUE). This equivalence was programmed as an ALTER to the SEMG SUBDMAP.

The programming of the SEMELRR main SUBDMAP consisted of writing an iterative procedure around the frequency response solution procedures, the geometric nonlinear matrix generation procedures, and the data recovery SUBDMAP, SUPER3, which includes the updated displacement calculations. To implement this iterative procedure, some of the files needed for the next iteration have to be saved. The module FILE to save or overwrite files was used for this purpose. Phase 3 procedures were included in the iteration loop because the updated displacements, necessary as input to the differential stiffness modules, are obtained from SUBDMAP SEDRCVR in Phase 3. SUBDMAP SEDRCVR had to be substantially rewritten to generate the correct updated displacements for the equivalent linearization procedure, equation (38). The calculation of the updated displacements will be discussed in depth in the following subsection. A full listing of the SEMELRR main SUBDMAP is provided in Appendix A.

The formation of the geometric nonlinear stiffness matrix in Phase 2 follows closely with the procedure in Nonlinear Transient solution sequence (NLTRAN, SOL 129). The linear dynamic equations of motion are solved first and the linear rms displacement vector $\{A\}$ is obtained. If the parameter LGDISP is greater than -1, the geometric nonlinear stiffness matrix KDJJ is formed from module EMA on the next iteration by applying this linear displacement vector. This geometric nonlinear stiffness matrix then reduces to KDLL, $[K_R]$ in equation (39). (If the parameter LGDISP equals -1, only the linear frequency response is calculated.) The equivalent linear stiffness matrix $[K_e]$ now consists of two matrices: the linear stiffness $[K]$ and the differential stiffness matrix $[K_R]$. The frequency response is then obtained using both geometric nonlinear and linear dynamic matrices.

This iteration method can be used to determine the rms displacements; however, it is slow to converge. An improved method for speeding up the convergence is to use an underrelaxation approach where displacements are not updated to their full values, but instead to the scale of the full values after each iteration. This method can be expressed as

$$\overline{\{Q\}}_{\text{current}} = (1 - \beta)\{Q\}_{\text{previous}} + \beta\{Q\}_{\text{current}} \tag{40}$$

A user-defined convergence enhancement parameter, β (BETA in DMAP programming), is introduced to scale the updated displacements. If the nonlinearity is mild to moderate, the convergence of the iteration procedure is faster for $0.5 \leq$ BETA ≤ 1.0. If the nonlinearity is severe, the convergence of the iteration procedure is faster for $0.0 <$ BETA ≤ 0.5. The parameter BETA is set by the user in the Bulk Data Deck.

Two user-defined parameters were introduced to control the termination of the iterative loop. The user-defined parameter MAXITER defines the maximum allowable number of iterations and the user-defined parameter MAXNORM sets the convergence criteria, i.e.

$$\left\| \overline{\{Q\}}_{\text{current}} - \overline{\{Q\}}_{\text{previous}} \right\| = \text{error} \leq \text{MAXNORM} \tag{41}$$

If the iteration count exceeds MAXITER or if the error norm, equation (41), is less than MAXNORM, the solution sequence will terminate normally. There is a warning message if the solution is not converged after the MAXITER iterations. There are two ways to handle convergence errors; the first is by increasing the number of allowable iterations, MAXITER, and the second is by choosing a different convergence enhancement parameter BETA, which is less than the previous BETA. A summary of the user-defined parameters and defaults is given in Appendix B.

3.2 Updated Displacement Calculation

The updated displacement vector is formed by multiplying the maximum rms displacement by the updated mode shapes. In order to do so, one deflection point number has to be obtained first by asking for XYPRINT (or XYPLOT) in the Control Deck of the MSC/NASTRAN data cards. In the SUBDMAP SEDRCVR, individual modes of the actual displacement vector are extracted. For each mode, the modal rms responses are calculated from module RANDOM. Each mode is normalized to unity for the largest component of the eigenvector. The actual rms response of each mode is then obtained by multiplying the rms response by the normalized eigenvector. The updated response of the structure can be calculated by using superposition of the modes and storing the updated rms displacement vector. This procedure entails the assumption that the modes and modal responses are independent. The modified SUBDMAP SEDRCVR is in Appendix C.

Although some minor modifications on SUBDMAP SUPER3 are made, no functional procedure was carried out. The modification passes parameters needed for communication between the main SUBDMAP and the SEDRCVR SUBDMAP. The modified SUBDMAP SUPER3 is included in Appendix D.

3.3 Output Requests

One new feature from the output request is for plotting the overall rms displacement output. In module RANDOM, only the rms values for a single degree of freedom are calculated. The actual overall rms displacement is formed by the updated mode shape at each iteration. Therefore, at the converged stage, the overall rms displacement can be extracted by using a DISP=ALL card in the Control Deck.

There is no rms strain response obtained from frequency random analysis of SOL 111. If rms element strain is required, the user-defined parameter RMSTRAIN has to be set to 1. For this case, the STRAIN=ALL card is needed in the Control Deck and the strains will be calculated.

Section 4 Validation of The SEMELRR Solution Sequence

The linearized random vibration capability developed for use with MSC/NASTRAN is validated by solving four problems and comparing the results with known solutions. The frequency response of free vibration and rms displacement response of forced random vibrations of a plate and a beam are considered. The results show that reasonable accuracy is achieved.

Problem 1: Random response of beams

The rms displacements of a 12–in × 2–in × 0.064–in aluminum beam with either end clamped or simply supported and subjected to uniformly distributed random loads is investigated. To demonstrate the accuracy of the SEMELRR results, approximate rms maximum deflections were obtained by using a separate Equivalent Linearization (EL) analysis [16] and finite element (FE) solution [7]. Results are shown in Figure 4. Since all three results (EL, FE, and SEMELRR) based on small deflection linear theory lie directly on top of one another, it is shown as one straight dotted and dashed line. The EL and FE results are identical for the linearized case, so one curve is plotted for these two methods. For acoustic excitations less than 90 dB for a simply supported case and 110 dB for a clamped case, the small deflection assumption yields good results. At high SSL, however, the small deflection theory overestimates the rms deflection, while it underestimates the frequency of vibration. It is clearly demonstrated that the SEMELRR results give reasonable predictions as compared to the EL and FE solutions in both linear and linearized cases.

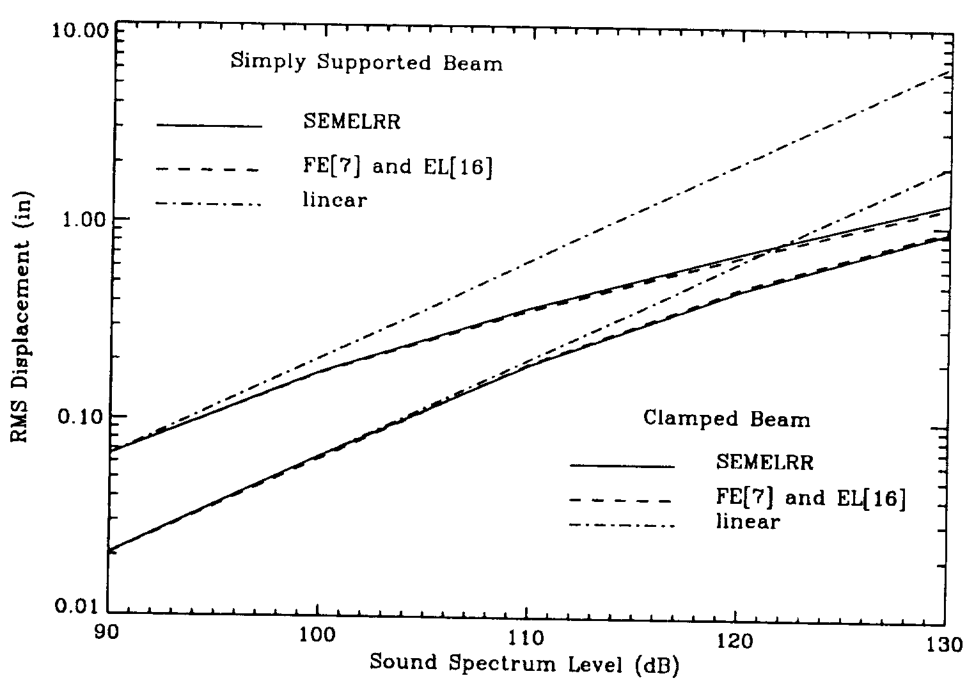

Figure 4: Effect of acoustic excitation level on maximum deflection for beams.

Problem 2: Random response of a clamped plate

The comparison is made for rms displacements as a function of SSL of an aluminum plate [7]. For acoustic excitations less than 100 dB, the small deflection assumption yields good results as shown in Figure 5. Above 100 dB, the large deflection formulation must be used. At the 130–dB level, the results between the SEMELRR and Locke's analysis [7] show a 6–percent difference. The discrepancy is attributable to the approximation of the nonlinear stiffness matrix in equation (39) and the assumption of curvatures and midsurface strains in the von Karman sense in Locke's formulation.

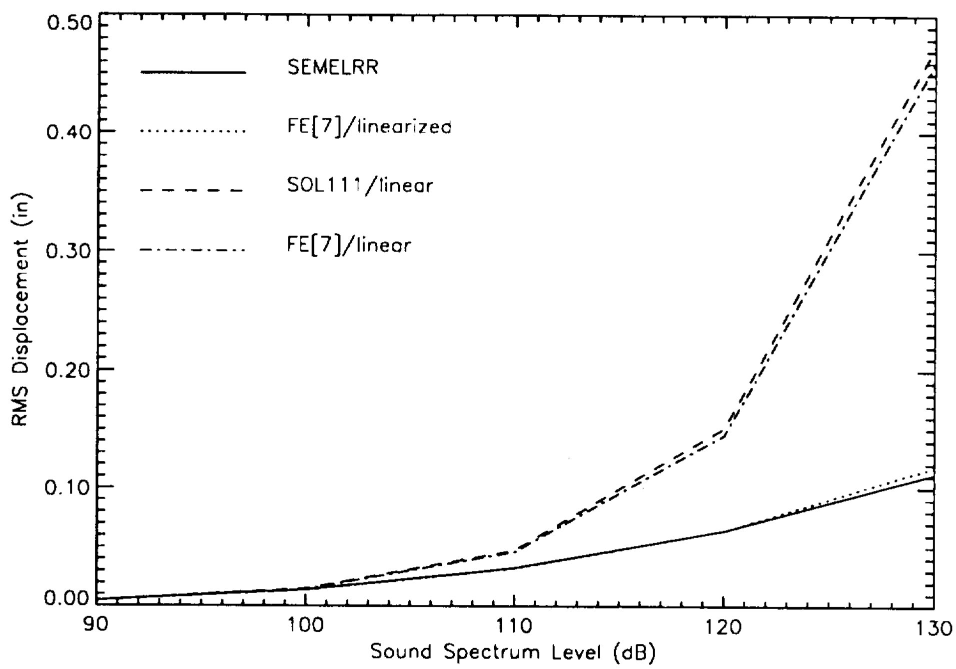

Figure 5: Effect on acoustic excitation level on maximum deflection for clamped plate.

Problem 3: Free vibration of rectangular plate

The free vibration of a 15–in × 12–in × 0.04–in aluminum rectangular plate reported in Chiang's paper [17] is used. The variation in SEMELRR free vibration results of a plate with all edges clamped for the frequency ratio ω/ω_0 at different amplitudes is shown in Figure 6. ω_0 is the fundamental frequency of the clamped plate. There is a maximum of 10–percent difference between the SEMELRR and Chiang's results. The frequency ratio for Chiang's results are lower. The differences are caused by two factors. First, Chiang's formulation used von Karman strain-displacement relations, which use thin plate assumptions, and therefore do not have all the terms in equation (1). The second is due to the approximation in equation (39). Because of this approximation, in which the first-order stiffness matrix in the SEMELRR is calculated one more time than the equivalent linearization approach, the linearized frequency is expected to be higher. These results show the SEMELRR procedure gives reasonable

predictions in comparison to finite element [17, 7] and equivalent linearization [16] solutions Figures, 4, 5, and 6.

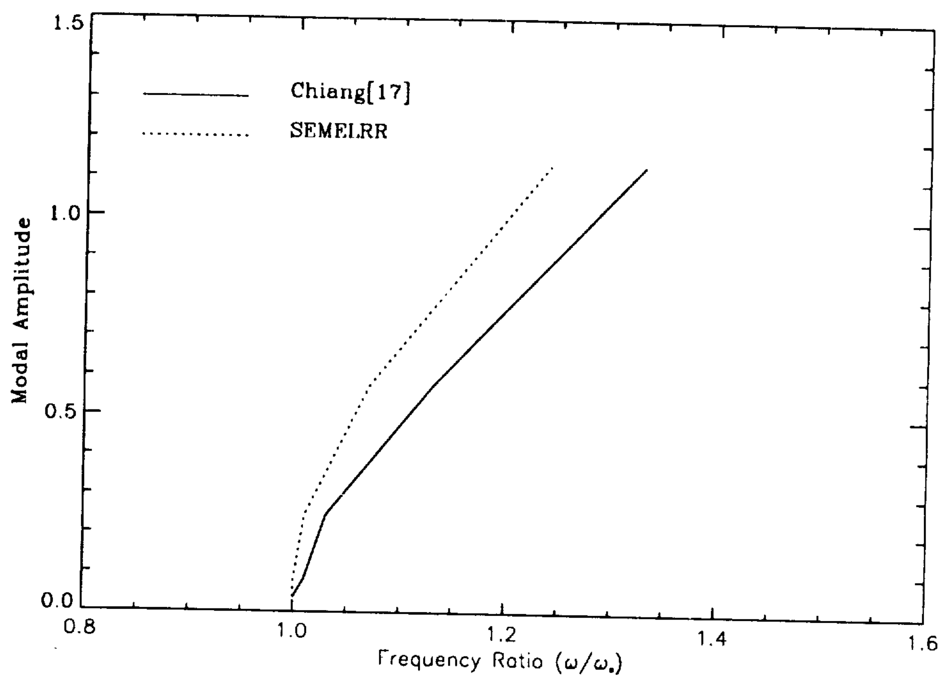

Figure 6: Amplitude versus frequency ratio for clamped plate.

Section 5 Example Problems

This section is intended to provide a series of simple analyses that demonstrate the capabilities and use of the equivalent linearization solution procedure as implemented in MSC/NASTRAN. The types of analyses used in this section were selected from a review of previously publisher papers [7, 16]. For simplicity these analyses share a common structural configuration, that of a simple rectangular panel. The thermo-acoustic response of a large hexagonal thermal acoustic protection panel is also presented to further demonstrate some of the features of the program. The format of this section follows closely that of the MSC/NASTRAN demonstration problems manual [18]. It is assumed in this section that the reader has a basic understanding of the basic NASTRAN CARDS and DECKS.

5.1 Problem Execution

The equivalent linearization solution sequence was written by incorporating portions of the NLSTATIC (SOL 106) solution sequence into the SEMFREQ (SOL 111) solution sequence. It is assumed in this manual that the reader has a basic understanding of the application, options, and limitations of both of those analyses.

MSC/NASTRAN performs random response analysis as post-processing to the frequency response. The Equivalent Linearization solution sequence is performed by including this post-processing in the iteration loop because the rms displacements, which are necessary as input to the differential stiffness modules, are obtained in Phase 3 procedure.

The SEMELRR solution sequence is not included in the MSC/NASTRAN-delivered data base, but is available as a separate DMAP program. The program must be read into the Executive Deck of the NASTRAN data file, and the individual SUBDMAPs and main SUBDMAP must be compiled and linked as part of each execution. The solution sequence can also be incorporated into the NASTRAN data base of solution sequences by creating a permanent USER.OBJ and USER.EXE as discussed in Chapter 7 of the "DMAP and DATA BASE APPLICATIONS" seminar notes [19]. The necessary commands to include, compile, link, and execute the solution sequence are provided in the example problems.

<u>Model Description</u>

The basic Bulk Data cards for the rectangular panel will be included in each example but will appear only here. The demonstration Bulk Data Deck includes the CQUAD4, GRID, SPC1, PSHELL, MAT2, and MAT8 cards. The rectangular aluminum plate is 12–in × 15–in × 0.04–in and is modeled using 64 QUAD4 elements with inplane and bending material property entries on the element PSHELL cards. The boundaries are assumed completely clamped. The zero displacements and rotations are enforced using SPC1 cards.

```
$
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....
$
CQUAD4  1       74      1       2       11      10      0.0
CQUAD4  2       74      2       3       12      11      0.0
CQUAD4  3       74      3       4       13      12      0.0
CQUAD4  4       74      4       5       14      13      0.0
CQUAD4  5       74      5       6       15      14      0.0
CQUAD4  6       74      6       7       16      15      0.0
CQUAD4  7       74      7       8       17      16      0.0
CQUAD4  8       74      8       9       18      17      0.0
CQUAD4  9       74      10      11      20      19      0.0
CQUAD4  10      74      11      12      21      20      0.0
CQUAD4  11      74      12      13      22      21      0.0
CQUAD4  12      74      13      14      23      22      0.0
CQUAD4  13      74      14      15      24      23      0.0
CQUAD4  14      74      15      16      25      24      0.0
CQUAD4  15      74      16      17      26      25      0.0
CQUAD4  16      74      17      18      27      26      0.0
CQUAD4  17      74      19      20      29      28      0.0
CQUAD4  18      74      20      21      30      29      0.0
CQUAD4  19      74      21      22      31      30      0.0
CQUAD4  20      74      22      23      32      31      0.0
CQUAD4  21      74      23      24      33      32      0.0
CQUAD4  22      74      24      25      34      33      0.0
CQUAD4  23      74      25      26      35      34      0.0
CQUAD4  24      74      26      27      36      35      0.0
CQUAD4  25      74      28      29      38      37      0.0
CQUAD4  26      74      29      30      39      38      0.0
CQUAD4  27      74      30      31      40      39      0.0
CQUAD4  28      74      31      32      41      40      0.0
CQUAD4  29      74      32      33      42      41      0.0
CQUAD4  30      74      33      34      43      42      0.0
CQUAD4  31      74      34      35      44      43      0.0
CQUAD4  32      74      35      36      45      44      0.0
CQUAD4  33      74      37      38      47      46      0.0
CQUAD4  34      74      38      39      48      47      0.0
CQUAD4  35      74      39      40      49      48      0.0
CQUAD4  36      74      40      41      50      49      0.0
CQUAD4  37      74      41      42      51      50      0.0
CQUAD4  38      74      42      43      52      51      0.0
CQUAD4  39      74      43      44      53      52      0.0
CQUAD4  40      74      44      45      54      53      0.0
CQUAD4  41      74      46      47      56      55      0.0
CQUAD4  42      74      47      48      57      56      0.0
CQUAD4  43      74      48      49      58      57      0.0
CQUAD4  44      74      49      50      59      58      0.0
CQUAD4  45      74      50      51      60      59      0.0
CQUAD4  46      74      51      52      61      60      0.0
CQUAD4  47      74      52      53      62      61      0.0
CQUAD4  48      74      53      54      63      62      0.0
CQUAD4  49      74      55      56      65      64      0.0
CQUAD4  50      74      56      57      66      65      0.0
CQUAD4  51      74      57      58      67      66      0.0
CQUAD4  52      74      58      59      68      67      0.0
CQUAD4  53      74      59      60      69      68      0.0
CQUAD4  54      74      60      61      70      69      0.0
CQUAD4  55      74      61      62      71      70      0.0
CQUAD4  56      74      62      63      72      71      0.0
CQUAD4  57      74      64      65      74      73      0.0
CQUAD4  58      74      65      66      75      74      0.0
CQUAD4  59      74      66      67      76      75      0.0
CQUAD4  60      74      67      68      77      76      0.0
CQUAD4  61      74      68      69      78      77      0.0
CQUAD4  62      74      69      70      79      78      0.0
CQUAD4  63      74      70      71      80      79      0.0
CQUAD4  64      74      71      72      81      80      0.0
$
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....
$
GRID    1               0.000   0.0     0.0
GRID    2               1.875   0.0     0.0
GRID    3               3.750   0.0     0.0
GRID    4               5.625   0.0     0.0
GRID    5               7.500   0.0     0.0
GRID    6               9.375   0.0     0.0
GRID    7               11.25   0.0     0.0
GRID    8               13.125  0.0     0.0
GRID    9               15.000  0.0     0.0
GRID    10              0.000   1.5     0.0
```

```
GRID    11              1.875   1.5     0.0
GRID    12              3.750   1.5     0.0
GRID    13              5.625   1.5     0.0
GRID    14              7.500   1.5     0.0
GRID    15              9.375   1.5     0.0
GRID    16              11.25   1.5     0.0
GRID    17              13.125  1.5     0.0
GRID    18              15.000  1.5     0.0
GRID    19              0.000   3.      0.0
GRID    20              1.875   3.      0.0
GRID    21              3.750   3.      0.0
GRID    22              5.625   3.      0.0
GRID    23              7.500   3.      0.0
GRID    24              9.375   3.      0.0
GRID    25              11.25   3.      0.0
GRID    26              13.125  3.      0.0
GRID    27              15.000  3.      0.0
GRID    28              0.000   4.5     0.0
GRID    29              1.875   4.5     0.0
GRID    30              3.750   4.5     0.0
GRID    31              5.625   4.5     0.0
GRID    32              7.500   4.5     0.0
GRID    33              9.375   4.5     0.0
GRID    34              11.25   4.5     0.0
GRID    35              13.125  4.5     0.0
GRID    36              15.000  4.5     0.0
GRID    37              0.000   6.      0.0
GRID    38              1.875   6.      0.0
GRID    39              3.750   6.      0.0
GRID    40              5.625   6.      0.0
GRID    41              7.500   6.      0.0
GRID    42              9.375   6.      0.0
GRID    43              11.25   6.      0.0
GRID    44              13.125  6.      0.0
GRID    45              15.000  6.      0.0
GRID    46              0.000   7.5     0.0
GRID    47              1.875   7.5     0.0
GRID    48              3.750   7.5     0.0
GRID    49              5.625   7.5     0.0
GRID    50              7.500   7.5     0.0
GRID    51              9.375   7.5     0.0
GRID    52              11.25   7.5     0.0
GRID    53              13.125  7.5     0.0
GRID    54              15.000  7.5     0.0
GRID    55              0.000   9.      0.0
GRID    56              1.875   9.      0.0
GRID    57              3.750   9.      0.0
GRID    58              5.625   9.      0.0
GRID    59              7.500   9.      0.0
GRID    60              9.375   9.      0.0
GRID    61              11.25   9.      0.0
GRID    62              13.125  9.      0.0
GRID    63              15.000  9.      0.0
GRID    64              0.000   10.5    0.0
GRID    65              1.875   10.5    0.0
GRID    66              3.750   10.5    0.0
GRID    67              5.625   10.5    0.0
GRID    68              7.500   10.5    0.0
GRID    69              9.375   10.5    0.0
GRID    70              11.25   10.5    0.0
GRID    71              13.125  10.5    0.0
GRID    72              15.000  10.5    0.0
GRID    73              0.000   12.     0.0
GRID    74              1.875   12.     0.0
GRID    75              3.750   12.     0.0
GRID    76              5.625   12.     0.0
GRID    77              7.500   12.     0.0
GRID    78              9.375   12.     0.0
GRID    79              11.25   12.     0.0
GRID    80              13.125  12.     0.0
GRID    81              15.000  12.     0.0
$
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....
$
SPC1    56      123456  1       THRU    9
SPC1    56      123456  10      19      28      37
SPC1    56      123456  18      27      36      45
SPC1    56      123456  46      55      64
SPC1    56      123456  54      63      72
SPC1    56      123456  73      THRU    81
```

```
$
PSHELL *              74       100000074  4.00000000E-02       200000074
*         1.00000000E+00               0  1.00000000E+00  0.00000000E+00
*        -2.00000000E-02  2.00000000E-02               0
MAT2   *       100000074  1.17831893E+07  3.88845247E+06  0.00000000E+00
*         1.17831893E+07  0.00000000E+00  3.94740000E+06  2.58800000E-04
*         0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
*         0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
*                      0
MAT2   *       200000074  1.17831893E+07  3.88845247E+06  0.00000000E+00
*         1.17831893E+07  0.00000000E+00  3.94740000E+06  2.58800000E-04
*         0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
*         0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
*                      0
MAT8    10        10.5+6  10.5+6  0.33    3.9474+6                2.588-4
$
```

Figure 7: Demonstration Bulk Data Deck

5.2 Linear Random Analysis

Problem Description

The random response of the plate subjected to broad-band acoustic excitation is first demonstrated. The spectral density functions of the selected displacements and element stresses are computed.

Executive Control Deck

The Executive Control Deck specifies that Structured Solution Sequence 111 (Modal Frequency Responses) is to be used to analyze the plate response under random loads.

```
ID PLATE,DEMO $
SOL 111 $
TIME 10 $
CEND $
```

Case Control Deck

METHOD	Specifies method by which the eigenvalues and eigenvectors will be extracted.
FREQ	Selects the set of frequencies to be solved in frequency response problems.
RANDOM	Random Analysis set selection
LOADSET	Selects a sequence of load sets referenced by dynamic load cards to be applied to the structural model.
DLOAD	Selects the dynamic load to be applied in a frequency response problem.
SDMAP	Selects table, which defines dampings as function of frequency.

```
SET 1 = 41
SET 2 = 1,2,3,4,5
DISPLACEMENT = 1
STRESS(FIBER) = 2
ECHO = PUNCH
TITLE = FLAT PLATE DEMO
SPC = 56
METHOD = 1
FREQ = 20
RANDOM = 59
LOADSET = 100
DLOAD = 301
SDAMP = 400
$ OUTPUT REQUESTS
OUTPUT(XYPLOT)
XYPLOT DISP PSDF/ 41(T3)
XYPLOT STRESS PSDF/ 3(3)
BEGIN BULK
```

The rms displacement can only be extracted from the data base PSDF in module RANDOM. The first card after OUTPUT of either XYPRINT DISP or XYPLOT DISP is needed in the Control Deck. If the rms displacement for the first card is zero, the process will stop and the fatal error message will be given. The output from the SEMELRR solution sequence is long, since it prints the output information for each iteration.

Bulk Data Deck

LSEQ	Defines a sequence of load sets referenced by dynamic load cards to be applied to the structural model. In this case, it is used to apply a unit pressure load to the plate since the Dynamic Load Scale Factor (DAREA) card can only handle the point load.
DLOAD	Defines a dynamic loading condition for frequency response.
RLOAD1	Defines a frequency-dependent dynamic load for use in frequency response problems.
FREQ1	Defines a set of frequencies to be analyzed.
RANDPS	Defines load set power spectral density factors for use in random analysis.
TABRND1	Defines power spectral density as a tabular function of frequency for use in random analysis. Referenced by the RANDPS entry.
TABDMPS	Defines modal damping as a tabular function of frequency.

```
EIGRL   1       0.1     4000.0  8
LSEQ    100     12      400
PLOAD2  400     1.      1       THRU    64
$
DLOAD   301     1.0     1.0     204
RLOAD1  204     12                      13
TABLED1 13                                                              +QR
+QR     0.0     1.0     3000.0  1.0     ENDT
$
FREQ1   20      00.1    1.0     1500
$
RANDPS  59      1       1       1.0             63
TABRND1 63                                                              +TR
+TR     -1.0    0.0     0.0     8.4215-53000.0  8.4215-53000.0  0.0     +TR2
+TR2    3001.0  0.0     ENDT
$
TABDMP1 400                                                             +DP1
+DP1    0.0     0.01    3000.0  0.01    ENDT
$
PARAM   NOCOMPS -1
$
```

Problem Output

```
 $ /cy/st/mco/mia/mscnas/msc/conf/nast67rc
1          N A S T R A N   S Y S T E M   P A R A M E T E R   E C H O          MARCH  29, 1993  MSC/NASTRAN   0/ 0/ 0   PAGE    0
0
     NASTRAN SYSTEM(149)=1 $ THIS IS FOR RAW IO
     NASTRAN BUFFSIZE=12289 $ CRI ASKED FOR THIS.
 $
1
0
0
0
0
0
0
0
                                        * * * * * * * * * * * * * * * * * * * *
                                        * * * * * * * * * * * * * * * * * * * *
                                        * *                                 * *
                                        * *                                 * *
                                        * *   M S C / N A S T R A N         * *
                                        * *                                 * *
                                        * *      VERSION - 67R2             * *
                                        * *                                 * *
                                        * *      JUL 29, 1992               * *
                                        * *                                 * *
                                        * *    Cray Research Inc.           * *
                                        * *                                 * *
                                        * *     MODEL CRAY Y-MP             * *
                                        * *                                 * *
                                        * *      UNICOS 6.1                 * *
                                        * *                                 * *
                                        * *       CRAY-YMP                  * *
                                        * * * * * * * * * * * * * * * * * * * *
                                        * * * * * * * * * * * * * * * * * * * *
1                                                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    1
0      N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O
0

     ID CHIANG,NASTRAN
     $
     SOL 111 $
     COMPILE SUBDMAP=SEDRCVR SOUIN=MSCSOU NOLIST NOREF $
     ALTER 168,169 $
     ENDALTER $
     TIME 30 $
     CEND $
1    TPS RESULTS ANALYSIS                                                      MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    2
0
0                                  C A S E   C O N T R O L   D E C K   E C H O
                CARD
                COUNT
                  1      $
                  2      SET 1 = 41
                  3      SET 2 = 1,2,3,4,5
                  4      DISPLACEMENT=1
                  5      STRAIN(FIBER) = 2
                  6      ECHO=PUNCH $
                  7      TITLE = TPS RESULTS ANALYSIS
                  8      SPC = 56
                  9      METHOD = 1
                 10      DLOAD =301
                 11      FREQ = 20
                 12      RANDOM = 59
                 13      SDAMP = 400
                 14      LOADSET=100
                 15      $
                 16      OUTPUT(XYOUT)
                 17      XYPLOT DISP PSDF/ 41(T3)
                 18      $
                 19      $     ELEMENT RMS STRESSES OUTPUT
                 20      $
                 21      XYPLOT STRESS PSDF/ 3(3)
```

```
                22      XYPLOT STRESS PSDF/ 3(5)
                23      XYPLOT STRESS PSDF/ 3(7)
                24      $
                25      BEGIN BULK
0                           INPUT BULK DATA CARD COUNT =     202
0                      TOTAL COUNT=   182
1    TPS RESULTS ANALYSIS
                                                                   MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE     3

0
0                                    SEQUENCE PROCESSOR OUTPUT


OTHERE ARE       81 POINTS DIVIDED INTO    1 GROUP(S).
0               CONNECTION DATA
OELEMENT TYPE       NUMBER    ASSEMBLY TIME(SEC)


   QUAD4              64           0.22
0---------------------------------------------
0
 TOTAL MATRIX ASSEMBLY TIME FOR       64 ELEMENTS IS     0.22 SECONDS.
OORIGINAL PERFORMANCE DATA
OSUPER(GROUP) ID   NO. GRIDS   AV. CONNECTIVITY   C-AVERAGE   C-RMS   C-MAXIMUM   P-GROUPS   P-AVERAGE   DECOMP TIME(SECS)
                                                                                                       (6.0 DOF/GRID )
0          0          81            7.72             9.89      10.15       11          0         0.00         0.037
ORESEQUENCED PERFORMANCE DATA
OSUPER(GROUP) ID   NO. GRIDS   AV. CONNECTIVITY   C-AVERAGE   C-RMS   C-MAXIMUM   P-GROUPS   P-AVERAGE   DECOMP TIME(SECS)  METHOD
                                                                                                       (6.0 DOF/GRID )
0          0          81            7.72             9.54       9.86       11          0         0.00         0.036        ACTIVE
1    TPS RESULTS ANALYSIS
                                                                   MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE     4

0
0                                                 OLOAD    RESULTANT
0             T1              T2              T3              R1              R2              R3
0       1  0.0000000E+00  0.0000000E+00  1.8000000E+02  1.0800000E+03 -1.3500000E+03  0.0000000E+00
1    TPS RESULTS ANALYSIS
                                                                   MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE     6

0

 LANCZOS PARAMETER VERIFICATION

     INITIAL PROBLEM SPECIFICATION
          DEGREES OF FREEDOM =       245              MESSAGE LEVEL        =          1              LEFT END POINT     -  3.948E-0001
          NUMBER OF MODES    =         1              OUTPUT UNIT          =          6              RIGHT END POINT    =  1.000E+2463
          MODE FLAG          =         1              SIZE OF WORKSPACE    =    2292687              CENTER FREQUENCY   =   0.0000E+00
          PROBLEM TYPE       =         1              MAXIMUM BLOCK SIZE   =          7              ACCURACY REQUIRED  =   3.6960E-10
          SHIFTING SCALE     =   3.4078E+05

     AFTER PROBLEM SPECIFICATION CHECKING
          NUMBER OF MODES    =         1              LEFT END POINT       =  3.948E-0001
          PROBLEM TYPE       =         1              RIGHT END POINT      =  1.000E+2463
          SHIFTING SCALE     =   3.4078E+05           CENTER FREQUENCY     =   0.0000E+00       CP TIME ALLOWED    =   1.7970E+03

     WORKSPACE ALLOCATION
          LANCZOS BLOCK SIZE =         2              MAX. RITZ VALUES     =        200         MAX. TRUST REGIONS =         25
          MAX. BLOCK STEPS   =       100              MAX. S.O. VECTORS    =        245
          MAX. MODES         =       245              WORKSPACE USED       =      44159

          NUMBER OF USER SUPPLIED VECTORS =         0

          NEW SHIFT          =   3.9478E-01           MODES STILL NEEDED =            1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  3.947842E-01, CYCLES =  1.000000E-01 NUMBER OF EIGENVALUES BELOW THIS VALUE =      0

     ACCEPTED EIGENVALUES
             2.5497E+05

          NEW SHIFT          =   5.2415E+05           MODES STILL NEEDED =            0
0*** USER INFORMATION MESSAGE 4158---STATISTICS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK SCRATCH  FOLLOW
           NUMBER OF NEGATIVE TERMS ON FACTOR DIAGONAL =      1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  5.241507E+05, CYCLES =  1.152254E+02 NUMBER OF EIGENVALUES BELOW THIS VALUE =      1

     END OF LANCZOS RUN
          WARNING FLAG          =          0
          NO. OF MODES COMPUTED =          1

     COMPUTED MODES
             2.54969705025038E+05
1    TPS RESULTS ANALYSIS
                                                                   MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE     7

0
0


                         E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (LANCZOS ITERATION)


                                BLOCK SIZE USED ......................    2

                                NUMBER OF DECOMPOSITIONS .............    2

                                NUMBER OF ROOTS FOUND ................    1

                                NUMBER OF SOLVES REQUIRED ............    6

                                TERMINATION MESSAGE :  REQUIRED NUMBER OF EIGENVALUES FOUND.
1    TPS RESULTS ANALYSIS
                                                                   MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE     8
0
                                              R E A L   E I G E N V A L U E S
   MODE    EXTRACTION      EIGENVALUE            RADIANS             CYCLES            GENERALIZED         GENERALIZED
    NO.       ORDER                                                                       MASS               STIFFNESS
      1         1        2.549697E+05        5.049452E+02        8.036453E+01        1.000000E+00        2.549697E+05
1    TPS RESULTS ANALYSIS
                                                                   MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE     9
```

```
0
0*** USER INFORMATION MESSAGE 5222 ,UNCOUPLED SOLUTION ALGORITHM USED.
1    TPS RESULTS ANALYSIS
                                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    10
0
1    TPS RESULTS ANALYSIS
                                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    11
0
0                             X Y - O U T P U T   S U M M A R Y  ( A U T O   O R   P S D F )
0 PLOT  CURVE FRAME                    RMS        NO. POSITIVE  XMIN FOR   XMAX FOR   YMIN FOR    X FOR     YMAX FOR    X FOR*
  TYPE   TYPE   NO.    CURVE ID.      VALUE         CROSSINGS   ALL DATA   ALL DATA   ALL DATA    YMIN      ALL DATA    YMAX
0 PSDF DISP      1       41(  5)   6.639258E-01  8.028730E+01  1.000E-01  1.500E+03  2.967E-10  1.500E+03  2.513E-01  8.010E+01
0 PSDF EL STR    2        3(  3)   4.744867E+03  8.028730E+01  1.000E-01  1.500E+03  1.516E-02  1.500E+03  1.283E+07  8.010E+01
1                                   * * * END OF JOB * * *
```

Figure 8: Output from linear random analysis

ALTER for Strain

Executive Control Deck

The spectral density of the strains can be obtained by using an ALTER of the modal frequency response solution sequence (SOL 111). This ALTER is placed in the Executive Control Deck and the solution sequence is compiled as shown.

```
ID PLATE,DEMO $

SOL 111 $

COMPILE SUBDMAP=SEDRCVR SOUIN=MSCSOU NOLIST NOREF $

ALTER 26 $

TYPE PARM,,I,N,OTAPE2 $

FILE PSDF=OVRWRT $

ALTER 186 $

      RANDOM XYCDBDR,DIT,MPSDL,OUGV2,OPG2,OQG2,OSTR2,OEF2,CASEDR/
                        PSDF,AUTO/S,N,NORAND $

ENDALTER $

TIME 10 $

CEND $
```

Case Control Deck

With the ALTER in the Executive Control Deck to acquire the strains, only one card needs to be changed. The change is on the STRAIN(FIBER) card. To obtain the strain, use the XYPLOT STRESS card. Use of the XYPLOT STRAIN card will cause the compiler to produce a fatal error. The other cards are used in the same order as for the linear random analysis.

```
SET 1 = 41

SET 2 = 1,2,3,4,5

DISPLACEMENT = 1

STRAIN(FIBER) = 2

ECHO = PUNCH

TITLE = FLAT PLATE DEMO

SPC = 56
```

```
METHOD = 1
FREQ = 20
RANDOM = 59
LOADSET = 100
DLOAD = 301
SDAMP = 400
$ OUTPUT REQUESTS
OUTPUT(XYPLOT)
XYPLOT DISP PSDF/ 41(T3)
XYPLOT STRESS PSDF/ 3(3)
BEGIN BULK
```

5.3 Nonlinear Random Analysis

Strain and Displacement Spectra

If the XYPRINT is used in the Case Control Deck, the output spectra with frequency increment can be found in the *.f06 file. The module FREQ1 in the Bulk Data Deck controls the starting frequency, frequency interval, and the number of frequency increments.

Problem Description

The nonlinear random response of the plate subjected to broad-band acoustic excitation is next demonstrated. The spectral density functions of the selected displacements and element stresses are computed.

Executive Control Deck

The Executive Control Deck specifies that the modified DMAP Modal Frequency Responses Structured Solution Sequence is to be compiled, linked, and used to analyze the plate response under random loads.

```
ACQUIRE NDDL $
ID PLATE,DEMO $
COMPILE SEMELRR SOUOUT=USROUT OBJOUT=USROBJ NOLIST NOREF $
INCLUDE SEMELRR.DMAP $
COMPILE SEDRCVR SOUOUT=USROUT OBJOUT=USROBJ NOLIST NOREF $
INCLUDE SEDRCVR.DMAP $
COMPILE SUPER3 SOUOUT=USROUT OBJOUT=USROBJ NOLIST NOREF $
INCLUDE SUPER3.DMAP $
COMPILE SUBDMAP=SEMO SOUIN=MSCSOU NOLIST NOREF $
ALTER 32 $
EQUIVX EST/ESTL/ALWAYS $
ENDALTER $
```

```
SOL SEMELRR $
LINK SEMELRR $
TIME 10 $
CEND $
```

Case Control Deck

Use the same Case Control Deck as for the linear random analysis.

Bulk Data Deck

Use the same Bulk Data Deck as for the linear random analysis. The following Parameters are needed in the Bulk Data Deck to proceed with the SEMELRR solution sequence.

PARAMeters

LGDISP	If linearized analysis is performed, set LGDISP=1. (default=−1)
RMSTRAIN	If rms strain is needed and print no output for STRESS=ALL in control deck, set RMSTRAIN=1. If rms strain is needed and print output for STRESS=ALL in control deck, set RMSTRAIN=2.
MAXITER	Maximum number of iterations. (default=5)
ABSNORM	Absolute norm for convergence test.
BETA	Convergence enhancement factor, ranging from 0.0 to 1.0, but not for 0.0. (default=0.5)

```
PARAM,RMSTRAIN,1 $ IF RMS STRAIN IS NEEDED, RMSTRAIN=1
PARAM,MAXITER,3 $ MAX. NUMBER OF ITERATION
PARAM,ABSNORM,2.0E-2 $ ABS. NORM FOR CONVERGENCE TEST
PARAM,BETA,0.5 $ SCALE FOR BETTER CONVERGENCE, RANGE FROM 0.0 TO 1.0 (BUT NOT 0.0)
PARAM,LGDISP,1 $ FOR LARGE DISPLACEMENT ANALYSIS, LGDISP=1
```

Problem Output

```
1    TPS RESULTS ANALYSIS                                  MARCH  29, 1993  MSC/NASTRAN  7/29/92  PAGE    5
0
0                                C A S E   C O N T R O L   D E C K   E C H O
           CARD
           COUNT
            1        $
            2        DISPLACEMENT  = ALL
            3        ECHO=NONE $
            4        TITLE = TPS RESULTS ANALYSIS
            5        SPC = 56
            6        METHOD = 1
            7        DLOAD =301
            8        FREQ = 20
            9        RANDOM = 59
```

```
              10       SDAMP = 400
              11       LOADSET=100
              12       $
              13       OUTPUT(XYOUT)
              14       XYPLOT DISP PSDF/ 41(T3)
              15       $
              16       BEGIN BULK
0                          INPUT BULK DATA CARD COUNT =      212
0                      TOTAL COUNT=   187
1    TPS RESULTS ANALYSIS                                                MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE     6

0
0                                   SEQUENCE PROCESSOR OUTPUT


OTHERE ARE       81 POINTS DIVIDED INTO    1 GROUP(S).
0            CONNECTION DATA
OELEMENT TYPE      NUMBER    ASSEMBLY TIME(SEC)


   QUAD4               64          0.22
0---------------------------------------------
0
 TOTAL MATRIX ASSEMBLY TIME FOR       64 ELEMENTS IS     0.22 SECONDS.
OORIGINAL PERFORMANCE DATA
OSUPER(GROUP) ID   NO. GRIDS   AV. CONNECTIVITY   C-AVERAGE   C-RMS   C-MAXIMUM   P-GROUPS   P-AVERAGE   DECOMP TIME(SECS)
                                                                                                        (6.0 DOF/GRID )
0          0          81            7.72            9.89      10.15       11          0         0.00        0.037
ORESEQUENCED PERFORMANCE DATA
OSUPER(GROUP) ID   NO. GRIDS   AV. CONNECTIVITY   C-AVERAGE   C-RMS   C-MAXIMUM   P-GROUPS   P-AVERAGE   DECOMP TIME(SECS)  METHOD
                                                                                                        (6.0 DOF/GRID )
0          0          81            7.72            9.54       9.86       11          0         0.00        0.036        ACTIVE
1    TPS RESULTS ANALYSIS                                                MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE     7

0
0                                          OLOAD    RESULTANT
0                 T1              T2              T3              R1              R2              R3
0       1   0.0000000E+00   0.0000000E+00   1.8000000E+02   1.0800000E+03  -1.3500000E+03   0.0000000E+00
1    TPS RESULTS ANALYSIS                                                MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE     8

0

 LANCZOS PARAMETER VERIFICATION

     INITIAL PROBLEM SPECIFICATION
          DEGREES OF FREEDOM =        245          MESSAGE LEVEL       =          1              LEFT END POINT     =  3.948E-0001
          NUMBER OF MODES    =          1          OUTPUT UNIT         =          6              RIGHT END POINT    =  1.000E+2463
          MODE FLAG          =          1          SIZE OF WORKSPACE   =    2292687              CENTER FREQUENCY   =  0.0000E+00
          PROBLEM TYPE       =          1          MAXIMUM BLOCK SIZE  =          7              ACCURACY REQUIRED  =  3.6960E-10
          SHIFTING SCALE     =   3.4078E+05

     AFTER PROBLEM SPECIFICATION CHECKING
          NUMBER OF MODES    =          1          LEFT END POINT      =  3.948E-0001
          PROBLEM TYPE       =          1          RIGHT END POINT     =  1.000E+2463
          SHIFTING SCALE     =   3.4078E+05        CENTER FREQUENCY    =   0.0000E+00             CP TIME ALLOWED    =   1.7900E+03

     WORKSPACE ALLOCATION
          LANCZOS BLOCK SIZE =          2          MAX. RITZ VALUES    =        200              MAX. TRUST REGIONS =        25
          MAX. BLOCK STEPS   =        100          MAX. S.O. VECTORS   =        245
          MAX. MODES         =        245          WORKSPACE USED      =      44159

          NUMBER OF USER SUPPLIED VECTORS =         0

          NEW SHIFT          =   3.9478E-01        MODES STILL NEEDED  =          1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  3.947842E-01, CYCLES =  1.000000E-01 NUMBER OF EIGENVALUES BELOW THIS VALUE =      0

     ACCEPTED EIGENVALUES
            2.5497E+05

          NEW SHIFT          =   5.2415E+05        MODES STILL NEEDED  =          0
0*** USER INFORMATION MESSAGE 4158---STATISTICS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK SCRATCH  FOLLOW
          NUMBER OF NEGATIVE TERMS ON FACTOR DIAGONAL =      1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION
     TRIAL EIGENVALUE =  5.241507E+05, CYCLES =  1.152254E+02 NUMBER OF EIGENVALUES BELOW THIS VALUE =      1

     END OF LANCZOS RUN
          WARNING FLAG              =          0
          NO. OF MODES COMPUTED =              1

     COMPUTED MODES
            2.5496970502503BE+05
1    TPS RESULTS ANALYSIS                                                MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    10

0
0


                         E I G E N V A L U E   A N A L Y S I S   S U M M A R Y    (LANCZOS ITERATION)



                                  BLOCK SIZE USED ......................     2

                                  NUMBER OF DECOMPOSITIONS .............     2

                                  NUMBER OF ROOTS FOUND ................     1

                                  NUMBER OF SOLVES REQUIRED ............     6

                                  TERMINATION MESSAGE :  REQUIRED NUMBER OF EIGENVALUES FOUND.
1    TPS RESULTS ANALYSIS                                                MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    11

0

                                                   R E A L   E I G E N V A L U E S
  MODE     EXTRACTION       EIGENVALUE            RADIANS              CYCLES              GENERALIZED          GENERALIZED
```

```
     NO.        ORDER                                                                  MASS                 STIFFNESS
       1          1        2.549697E+05        5.049452E+02        8.036453E+01       1.000000E+00        2.549697E+05
1    TPS RESULTS ANALYSIS                                                     MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    12

0
0*** USER INFORMATION MESSAGE 5222 ,UNCOUPLED SOLUTION ALGORITHM USED.
1    TPS RESULTS ANALYSIS                                                     MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    13

0
 ^^^THIS IS MODE #            1
 ^^^(09-22-92)KNT=          -1LNODES=          1
 ^^^NO. OF COLUMNS=           1
1    TPS RESULTS ANALYSIS                                                     MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    14

0
 ^^^OSTR2(09-14-92)=               -1
1    TPS RESULTS ANALYSIS                                                     MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    15

0
0                         X Y - O U T P U T   S U M M A R Y  ( A U T O   O R   P S D F )
0 PLOT  CURVE FRAME                       RMS        NO. POSITIVE   XMIN FOR   XMAX FOR   YMIN FOR    X FOR     YMAX FOR     X FOR*
  TYPE   TYPE   NO.    CURVE ID.          VALUE        CROSSINGS    ALL DATA   ALL DATA   ALL DATA     YMIN     ALL DATA      YMAX
0 PSDF DISP       1         41(  5)    6.639258E-01  8.028730E+01  1.000E-01  1.500E+03  2.967E-10  1.500E+03  2.513E-01  8.010E+01
 ^^^RMSDIS1=       6.639258E-0125=    6.639258E-01
 ^^^NODES=          410
 ^^^MODENO CON1 NODEDIS=        41        243  1.000000E+00
 ^^^FREQUENCY=     8.028730E+01
 ^^^RMSDIS1=       6.639258E-01
 ^^^THE RMS DIS. AT POINT           41 IS    6.639258E-01 WITH TOTAL OF            1 MODES
 ^^^LOCALMAX=      6.639258E-01 LOCALMIN=     1.680173E-01
 ^^^THE MAX RMS DIS. IS    6.639258E-01
0*** USER INFORMATION MESSAGE 4110 (OUTPX2)END-OF-DATA SIMULATION ON FORTRAN UNIT 12
                              (MAXIMUM SIZE OF FORTRAN RECORDS WRITTEN =        1 WORDS.)
                                 (NUMBER OF FORTRAN RECORDS WRITTEN =        1 RECORDS.)
                                 (TOTAL DATA WRITTEN FOR EOF MARKER =        1 WORDS.)
1    TPS RESULTS ANALYSIS                                                     MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    16

0

 LANCZOS PARAMETER VERIFICATION

     INITIAL PROBLEM SPECIFICATION
          DEGREES OF FREEDOM =        245            MESSAGE LEVEL       =          1            LEFT END POINT     =  3.948E-0001
          NUMBER OF MODES    =          1            OUTPUT UNIT         =          6            RIGHT END POINT    =  1.000E+2463
          MODE FLAG          =          1            SIZE OF WORKSPACE   =    2292687            CENTER FREQUENCY   =   0.0000E+00
          PROBLEM TYPE       =          1            MAXIMUM BLOCK SIZE  =          7            ACCURACY REQUIRED  =   3.6960E-10
          SHIFTING SCALE     =    6.2573E+05

     AFTER PROBLEM SPECIFICATION CHECKING
          NUMBER OF MODES    =          1            LEFT END POINT      =  3.948E-0001
          PROBLEM TYPE       =          1            RIGHT END POINT     =  1.000E+2463
          SHIFTING SCALE     =    6.2573E+05         CENTER FREQUENCY    =   0.0000E+00         CP TIME ALLOWED    =   1.7780E+03

     WORKSPACE ALLOCATION
          LANCZOS BLOCK SIZE =          2            MAX. RITZ VALUES    =        200            MAX. TRUST REGIONS =         25
          MAX. BLOCK STEPS   =        100            MAX. S.O. VECTORS   =        245
          MAX. MODES         =        245            WORKSPACE USED      =      44159

          NUMBER OF USER SUPPLIED VECTORS =          0

          NEW SHIFT          =    3.9478E-01         MODES STILL NEEDED =           1
0*** USER INFORMATION MESSAGE 5010. STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  3.947842E-01, CYCLES =  1.000000E-01 NUMBER OF EIGENVALUES BELOW THIS VALUE =      0

     ACCEPTED EIGENVALUES
            2.1964E+07      3.2674E+07

          NEW SHIFT          =    2.7319E+07         MODES STILL NEEDED =          -1
0*** USER INFORMATION MESSAGE 4158---STATISTICS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK SCRATCH  FOLLOW
           NUMBER OF NEGATIVE TERMS ON FACTOR DIAGONAL =      1
0*** USER INFORMATION MESSAGE 5010. STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  2.731899E+07, CYCLES =  8.318643E+02 NUMBER OF EIGENVALUES BELOW THIS VALUE =      1

     END OF LANCZOS RUN
          WARNING FLAG          =          0
          NO. OF MODES COMPUTED =          1

     COMPUTED MODES
            2.19639580217577E+07
1    TPS RESULTS ANALYSIS                                                     MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    17

0
0


                         E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (LANCZOS ITERATION)


                                     BLOCK SIZE USED ......................    2

                                     NUMBER OF DECOMPOSITIONS .............    2

                                     NUMBER OF ROOTS FOUND ................    1

                                     NUMBER OF SOLVES REQUIRED ............    8

                                     TERMINATION MESSAGE :  REQUIRED NUMBER OF EIGENVALUES FOUND.
1    TPS RESULTS ANALYSIS                                                     MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    18

0

                                          R E A L   E I G E N V A L U E S
   MODE    EXTRACTION      EIGENVALUE          RADIANS            CYCLES            GENERALIZED          GENERALIZED
    NO.       ORDER                                                                     MASS               STIFFNESS
      1          1        2.196396E+07        4.686572E+03        7.458911E+02       1.000000E+00        2.196396E+07
1    TPS RESULTS ANALYSIS                                                     MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    19
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0
0*** USER INFORMATION MESSAGE 5222 ,UNCOUPLED SOLUTION ALGORITHM USED.
1    TPS RESULTS ANALYSIS                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    20

0
 ***THIS IS MODE #              1
 ***(09-22-92)KNT=           OLMODES=          1
 ***NO. OF COLUMNS=             1
1    TPS RESULTS ANALYSIS                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    21

0
 ***OSTR2(09-14-92)=                 -1
1    TPS RESULTS ANALYSIS                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    22

0
0                             X Y - O U T P U T   S U M M A R Y   ( A U T O   O R   P S D F )
0 PLOT  CURVE FRAME                        RMS        NO. POSITIVE   XMIN FOR   XMAX FOR   YMIN FOR    X FOR     YMAX FOR    X FOR*
  TYPE   TYPE   NO.    CURVE ID.          VALUE         CROSSINGS    ALL DATA   ALL DATA   ALL DATA    YMIN      ALL DATA     YMAX
0 PSDF DISP       2         41(  5)    1.723170E-02  7.445945E+02  1.000E-01  1.500E+03  2.735E-10  1.500E+03  2.526E-05  7.461E+02
 ***RMSDIS1=       1.723170E-02Z5=    1.723170E-02
 ***MODES=         410
 ***MODENO CON1 MODEDIS=          41         243   9.835657E-01
 ***FREQUENCY=     7.445945E+02
 ***RMSDIS1=       1.751962E-02
 ***THE RMS DIS. AT POINT              41 IS    1.723170E-02 WITH TOTAL OF            1 MODES
 ***LOCALMAX=      1.751962E-02 LOCALMIN=     6.410041E-03
 ***THE MAX RMS DIS. IS    1.751962E-02
0*** USER INFORMATION MESSAGE 4110 (OUTPX2) END-OF-DATA SIMULATION ON FORTRAN UNIT 12
                                (MAXIMUM SIZE OF FORTRAN RECORDS WRITTEN =       1 WORDS.)
                                     (NUMBER OF FORTRAN RECORDS WRITTEN =       1 RECORDS.)
                                     (TOTAL DATA WRITTEN FOR EOF MARKER =       1 WORDS.)
 *** ITERATION NO.(-1=LINEAR)=              0 XNORM=    3.147312E-01
 ***UGNIMAX=       3.319629E-01
 ***MUGNIMAX=      1.751962E-02
 ***ABSOLUTE NORM =    1.794806E+01
1    TPS RESULTS ANALYSIS                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    23

0

 LANCZOS PARAMETER VERIFICATION

    INITIAL PROBLEM SPECIFICATION
         DEGREES OF FREEDOM =        245            MESSAGE LEVEL        =          1              LEFT END POINT       =  3.948E-0001
         NUMBER OF MODES    =          1            OUTPUT UNIT          =          6              RIGHT END POINT      =  1.000E+2463
         MODE FLAG          =          1            SIZE OF WORKSPACE    =    2292687              CENTER FREQUENCY     =   0.0000E+00
         PROBLEM TYPE       =          1            MAXIMUM BLOCK SIZE   =          7              ACCURACY REQUIRED    =   3.6960E-10
         SHIFTING SCALE     =   4.2479E+05

    AFTER PROBLEM SPECIFICATION CHECKING
         NUMBER OF MODES    =          1            LEFT END POINT       =  3.948E-0001
         PROBLEM TYPE       =          1            RIGHT END POINT      =  1.000E+2463
         SHIFTING SCALE     =   4.2479E+05          CENTER FREQUENCY     =   0.0000E+00              CP TIME ALLOWED      =   1.7660E+03

    WORKSPACE ALLOCATION
         LANCZOS BLOCK SIZE =          2            MAX. RITZ VALUES     =        200              MAX. TRUST REGIONS =         25
         MAX. BLOCK STEPS   =        100            MAX. S.O. VECTORS    =        245
         MAX. MODES         =        245            WORKSPACE USED       =      44159

         NUMBER OF USER SUPPLIED VECTORS =          0

         NEW SHIFT          =   3.9478E-01          MODES STILL NEEDED =             1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  3.947842E-01, CYCLES =  1.000000E-01 NUMBER OF EIGENVALUES BELOW THIS VALUE =      0

     ACCEPTED EIGENVALUES
           9.3066E+06

         NEW SHIFT          =   1.1172E+07          MODES STILL NEEDED =             0
0*** USER INFORMATION MESSAGE 4158---STATISTICS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK SCRATCH  FOLLOW
          NUMBER OF NEGATIVE TERMS ON FACTOR DIAGONAL =      1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  1.117194E+07, CYCLES =  5.319668E+02 NUMBER OF EIGENVALUES BELOW THIS VALUE =      1

     END OF LANCZOS RUN
         WARNING FLAG         =          0
         NO. OF MODES COMPUTED =         1

     COMPUTED MODES
           9.30658624907690E+06
1    TPS RESULTS ANALYSIS                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    24

0
0

                         E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (LANCZOS ITERATION)


                     -            BLOCK SIZE USED ......................      2

                                  NUMBER OF DECOMPOSITIONS .............      2

                                  NUMBER OF ROOTS FOUND ................      1

                                  NUMBER OF SOLVES REQUIRED ............      8

                                  TERMINATION MESSAGE :  REQUIRED NUMBER OF EIGENVALUES FOUND.
1    TPS RESULTS ANALYSIS                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    25

0
                                               R E A L   E I G E N V A L U E S
   MODE    EXTRACTION      EIGENVALUE          RADIANS            CYCLES            GENERALIZED         GENERALIZED
    NO.       ORDER                                                                     MASS              STIFFNESS
       1          1        9.306586E+06       3.050670E+03       4.855292E+02       1.000000E+00       9.306586E+06
1    TPS RESULTS ANALYSIS                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    26
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0
0*** USER INFORMATION MESSAGE 5222 ,UNCOUPLED SOLUTION ALGORITHM USED.
1    TPS RESULTS ANALYSIS
                                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    27

0
 ***THIS IS MODE #            1
 ***(09-22-92)KNT=            1LMODES=          1
 ***NO. OF COLUMNS=           1
1    TPS RESULTS ANALYSIS
                                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    28

0
 ***OSTR2(09-14-92)=             -1
1    TPS RESULTS ANALYSIS
                                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    29

0
0                          X Y - O U T P U T   S U M M A R Y   ( A U T O   O R   P S D F )
0 PLOT  CURVE FRAME                            RMS        NO. POSITIVE   XMIN FOR   XMAX FOR   YMIN FOR    X FOR     YMAX FOR    X FOR*
  TYPE   TYPE  NO.     CURVE ID.               VALUE        CROSSINGS    ALL DATA   ALL DATA   ALL DATA    YMIN      ALL DATA    YMAX
0 PSDF DISP     3        41( 5)    3.744705E-02  4.850105E+02  1.000E-01  1.500E+03  2.518E-10  1.500E+03  1.786E-04  4.851E+02
 ***RMSDIS1=      3.744705E-02Z5=   3.744705E-02
 ***MODES=         410
 ***MODENO CON1 MODEDIS=         41         243 -1.000000E+00
 ***FREQUENCY=     4.850105E+02
 ***RMSDIS1=       3.744705E-02
 ***THE RMS DIS. AT POINT             41 IS   3.744705E-02 WITH TOTAL OF            1 MODES
 ***LOCALMAX=      1.143962E-02 LOCALMIN=    3.744705E-02
 ***THE MAX RMS DIS. IS    3.744705E-02
0*** USER INFORMATION MESSAGE 4110 (OUTPX2)END-OF-DATA SIMULATION ON FORTRAN UNIT 12
                               (MAXIMUM SIZE OF FORTRAN RECORDS WRITTEN =       1 WORDS.)
                                    (NUMBER OF FORTRAN RECORDS WRITTEN =        1 RECORDS.)
                                    (TOTAL DATA WRITTEN FOR EOF MARKER =        1 WORDS.)
 *** ITERATION NO.(-1=LINEAR)=              1 XNORM=    1.371502E-01
 ***UGNIMAX=        1.745973E-01
 ***MUGNIMAX=       3.744705E-02
 ***ABSOLUTE NORM =    3.662511E+00
1    TPS RESULTS ANALYSIS
                                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    30

0

 LANCZOS PARAMETER VERIFICATION

     INITIAL PROBLEM SPECIFICATION
          DEGREES OF FREEDOM =        245             MESSAGE LEVEL       =          1              LEFT END POINT      =  3.948E-0001
          NUMBER OF MODES    =          1             OUTPUT UNIT         =          6              RIGHT END POINT     =  1.000E+2463
          MODE FLAG          =          1             SIZE OF WORKSPACE   =    2292687              CENTER FREQUENCY    =   0.0000E+00
          PROBLEM TYPE       =          1             MAXIMUM BLOCK SIZE  =          7              ACCURACY REQUIRED   =   3.6960E-10
          SHIFTING SCALE     =   3.7184E+05

     AFTER PROBLEM SPECIFICATION CHECKING
          NUMBER OF MODES    =          1             LEFT END POINT      =  3.948E-0001
          PROBLEM TYPE       =          1             RIGHT END POINT     =  1.000E+2463
          SHIFTING SCALE     =   3.7184E+05           CENTER FREQUENCY    =   0.0000E+00            CP TIME ALLOWED     =   1.7550E+03

     WORKSPACE ALLOCATION
          LANCZOS BLOCK SIZE =          2             MAX. RITZ VALUES    =        200              MAX. TRUST REGIONS =          25
          MAX. BLOCK STEPS   =        100             MAX. S.O. VECTORS   =        245
          MAX. MODES         =        245             WORKSPACE USED      =      44159

          NUMBER OF USER SUPPLIED VECTORS =        0

          NEW SHIFT          =   3.9478E-01           MODES STILL NEEDED =            1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  3.947842E-01, CYCLES =  1.000000E-01 NUMBER OF EIGENVALUES BELOW THIS VALUE =      0

     ACCEPTED EIGENVALUES
             5.0082E+06

          NEW SHIFT          =   5.9618E+06           MODES STILL NEEDED =            0
0*** USER INFORMATION MESSAGE 4158---STATISTICS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK SCRATCH  FOLLOW
          NUMBER OF NEGATIVE TERMS ON FACTOR DIAGONAL =      1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  5.961836E+06, CYCLES =  3.886066E+02 NUMBER OF EIGENVALUES BELOW THIS VALUE =      1

     END OF LANCZOS RUN
          WARNING FLAG             =          0
          NO. OF MODES COMPUTED =             1

     COMPUTED MODES
             5.00817975026906E+06
1    TPS RESULTS ANALYSIS
                                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    31

0
0


                      E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (LANCZOS ITERATION)


                                     BLOCK SIZE USED ......................     2

                                     NUMBER OF DECOMPOSITIONS .............     2

                                     NUMBER OF ROOTS FOUND ................     1

                                     NUMBER OF SOLVES REQUIRED ............     6

                                     TERMINATION MESSAGE :  REQUIRED NUMBER OF EIGENVALUES FOUND.
1    TPS RESULTS ANALYSIS
                                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    32

0

                                              R E A L   E I G E N V A L U E S
  MODE    EXTRACTION      EIGENVALUE             RADIANS              CYCLES            GENERALIZED          GENERALIZED
   NO.       ORDER                                                                          MASS               STIFFNESS
    1          1          5.008180E+06        2.237896E+03         3.561723E+02        1.000000E+00         5.008180E+06
1    TPS RESULTS ANALYSIS
                                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    33
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0
0*** USER INFORMATION MESSAGE 5222 ,UNCOUPLED SOLUTION ALGORITHM USED.
1    TPS RESULTS ANALYSIS                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    34

0
 ***THIS IS MODE #           1
 ***(09-22-92)KNT=          2LMODES=         1
 ***NO. OF COLUMNS=          1
1    TPS RESULTS ANALYSIS                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    35

0
 ***OSTR2(09-14-92)=            -1
1    TPS RESULTS ANALYSIS                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    36

0
0                           X Y - O U T P U T   S U M M A R Y   ( A U T O   O R   P S D F )
0 PLOT  CURVE FRAME                          RMS        NO. POSITIVE   XMIN FOR   XMAX FOR   YMIN FOR    X FOR      YMAX FOR    X FOR*
  TYPE   TYPE   NO.     CURVE ID.           VALUE        CROSSINGS    ALL DATA   ALL DATA   ALL DATA    YMIN       ALL DATA    YMAX
0 PSDF DISP      4       41(  5)     7.054338E-02  3.558983E+02  1.000E-01  1.500E+03  3.175E-10  1.500E+03  8.884E-04  3.561E+02
 ***RMSDIS1=      7.054338E-02Z5=   7.054338E-02
 ***MODES=         410
 ***MODENO CON1 MODEDIS=        41        243 -1.000000E+00
 ***FREQUENCY=     3.558983E+02
 ***RMSDIS1=       7.054338E-02
 ***THE RMS DIS. AT POINT              41 IS   7.054338E-02 WITH TOTAL OF          1 MODES
 ***LOCALMAX=      1.549021E-02 LOCALMIN=     7.054338E-02
 ***THE MAX RMS DIS. IS   7.054338E-02
0*** USER INFORMATION MESSAGE 4110 (OUTPX2)END-OF-DATA SIMULATION ON FORTRAN UNIT 12
                             (MAXIMUM SIZE OF FORTRAN RECORDS WRITTEN =        1 WORDS.)
                                   (NUMBER OF FORTRAN RECORDS WRITTEN =        1 RECORDS.)
                                   (TOTAL DATA WRITTEN FOR EOF MARKER =        1 WORDS.)
 *** ITERATION NO.(-1=LINEAR)=           2 XNORM=   3.547879E-02
 ***UGNIMAX=       1.060222E-01
 ***MUGNIMAX=      7.054338E-02
 ***ABSOLUTE NORM =    5.029357E-01
1    TPS RESULTS ANALYSIS                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    37

0

 LANCZOS PARAMETER VERIFICATION

     INITIAL PROBLEM SPECIFICATION
          DEGREES OF FREEDOM =        245          MESSAGE LEVEL        =          1          LEFT END POINT      =  3.948E-0001
          NUMBER OF MODES    =          1          OUTPUT UNIT          =          6          RIGHT END POINT     =  1.000E+2463
          MODE FLAG          =          1          SIZE OF WORKSPACE    =    2292687          CENTER FREQUENCY    =   0.0000E+00
          PROBLEM TYPE       =          1          MAXIMUM BLOCK SIZE   =          7          ACCURACY REQUIRED   =   3.6960E-10
          SHIFTING SCALE     =   3.6230E+05

     AFTER PROBLEM SPECIFICATION CHECKING
          NUMBER OF MODES    =          1          LEFT END POINT       =  3.948E-0001
          PROBLEM TYPE       =          1          RIGHT END POINT      =  1.000E+2463
          SHIFTING SCALE     =   3.6230E+05        CENTER FREQUENCY     =   0.0000E+00        CP TIME ALLOWED     =   1.7430E+03

     WORKSPACE ALLOCATION
          LANCZOS BLOCK SIZE =          2          MAX. RITZ VALUES     =        200          MAX. TRUST REGIONS =         25
          MAX. BLOCK STEPS   =        100          MAX. S.O. VECTORS    =        245
          MAX. MODES         =        245          WORKSPACE USED       =      44159

          NUMBER OF USER SUPPLIED VECTORS =        0

          NEW SHIFT          =   3.9478E-01        MODES STILL NEEDED =            1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  3.947842E-01, CYCLES =  1.000000E-01 NUMBER OF EIGENVALUES BELOW THIS VALUE =       0

     ACCEPTED EIGENVALUES
             3.7661E+06

          NEW SHIFT          =   4.5886E+06        MODES STILL NEEDED =            0
0*** USER INFORMATION MESSAGE 4158---STATISTICS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK SCRATCH  FOLLOW
          NUMBER OF NEGATIVE TERMS ON FACTOR DIAGONAL =       1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  4.588630E+06, CYCLES =  3.409272E+02 NUMBER OF EIGENVALUES BELOW THIS VALUE =       1

     END OF LANCZOS RUN
          WARNING FLAG            =          0
          NO. OF MODES COMPUTED   =          1

     COMPUTED MODES
             3.766129250286680E+06
1    TPS RESULTS ANALYSIS                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    38

0
0


                       E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (LANCZOS ITERATION)


                                BLOCK SIZE USED ......................     2

                                NUMBER OF DECOMPOSITIONS .............     2

                                NUMBER OF ROOTS FOUND ................     1

                                NUMBER OF SOLVES REQUIRED ............     8

                                TERMINATION MESSAGE :  REQUIRED NUMBER OF EIGENVALUES FOUND.
1    TPS RESULTS ANALYSIS                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    39

0

                                          R E A L   E I G E N V A L U E S
   MODE    EXTRACTION      EIGENVALUE          RADIANS            CYCLES            GENERALIZED         GENERALIZED
    NO.       ORDER                                                                     MASS               STIFFNESS
       1         1        3.766129E+06      1.940652E+03      3.088643E+02       1.000000E+00        3.766129E+06
1    TPS RESULTS ANALYSIS                                                  MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    40
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 0
 0*** USER INFORMATION MESSAGE 5222 .UNCOUPLED SOLUTION ALGORITHM USED.
 1    TPS RESULTS ANALYSIS                                                      MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    41

 0
 ***THIS IS NODE #          1
 ***(09-22-92)KNT=          1LNODES=        1
 ***NO. OF COLUMNS=         1
 1    TPS RESULTS ANALYSIS                                                      MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    42

 0
 ***OSTR2(09-14-92)=           -1
 1    TPS RESULTS ANALYSIS                                                      MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    43

 0
 0                         X Y - O U T P U T  S U M M A R Y  ( A U T O  O R  P S D F )
 0 PLOT  CURVE FRAME                    RMS        NO. POSITIVE  XMIN FOR   XMAX FOR   YMIN FOR    X FOR     YMAX FOR    X FOR*
  TYPE   TYPE  NO.    CURVE ID.         VALUE        CROSSINGS   ALL DATA   ALL DATA   ALL DATA    YMIN      ALL DATA    YMAX
 0 PSDF DISP     5      41(  5)    9.195319E-02  3.086597E+02  1.000E-01  1.500E+03  3.416E-10  1.500E+03  1.701E-03  3.091E+02
 ***RMSDIS1=      9.195319E-0225=   9.195319E-02
 ***NODES=         410
 ***NODENO CON1 NODEDIS=       41        243  1.000000E+00
 ***FREQUENCY=    3.086597E+02
 ***RMSDIS1=      9.195319E-02
 ***THE RMS DIS. AT POINT            41 IS   9.195319E-02 WITH TOTAL OF          1 NODES
 ***LOCALMAX=     9.195319E-02 LOCALMIN=     1.972773E-02
 ***THE MAX RMS DIS. IS    9.195319E-02
0*** USER INFORMATION MESSAGE 4110 (OUTPX2)END-OF-DATA SIMULATION ON FORTRAN UNIT 12
                            (MAXIMUM SIZE OF FORTRAN RECORDS WRITTEN =       1 WORDS.)
                                 (NUMBER OF FORTRAN RECORDS WRITTEN =       1 RECORDS.)
                                 (TOTAL DATA WRITTEN FOR EOF MARKER =       1 WORDS.)
 *** ITERATION NO.(-1=LINEAR)=           3 XNORM=    3.670415E-03
 ***UGNIMAX=       8.828278E-02
 ***NUGNIMAX=      9.195319E-02
 ***ABSOLUTE NORM =  -3.991613E-02
 1    TPS RESULTS ANALYSIS                                                      MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    44

 0

 LANCZOS PARAMETER VERIFICATION

     INITIAL PROBLEM SPECIFICATION
         DEGREES OF FREEDOM =        245          MESSAGE LEVEL       =         1          LEFT END POINT     =  3.948E-0001
         NUMBER OF MODES    =          1          OUTPUT UNIT         =         6          RIGHT END POINT    =  1.000E+2463
         MODE FLAG          =          1          SIZE OF WORKSPACE   =   2292687          CENTER FREQUENCY   =   0.0000E+00
         PROBLEM TYPE       =          1          MAXIMUM BLOCK SIZE  =         7          ACCURACY REQUIRED  =   3.6960E-10
         SHIFTING SCALE     =    3.6252E+05

     AFTER PROBLEM SPECIFICATION CHECKING
         NUMBER OF MODES    =          1          LEFT END POINT      =  3.948E-0001
         PROBLEM TYPE       =          1          RIGHT END POINT     =  1.000E+2463
         SHIFTING SCALE     =    3.6252E+05       CENTER FREQUENCY    =   0.0000E+00          CP TIME ALLOWED    =   1.7310E+03

     WORKSPACE ALLOCATION
         LANCZOS BLOCK SIZE =          2          MAX. RITZ VALUES    =       200          MAX. TRUST REGIONS =      25
         MAX. BLOCK STEPS   =        100          MAX. S.O. VECTORS   =       245
         MAX. MODES         =        245          WORKSPACE USED      =     44159

         NUMBER OF USER SUPPLIED VECTORS =        0

         NEW SHIFT          =    3.9478E-01       MODES STILL NEEDED  =         1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  3.947842E-01, CYCLES =  1.000000E-01 NUMBER OF EIGENVALUES BELOW THIS VALUE =     0

     ACCEPTED EIGENVALUES
             3.7618E+06

         NEW SHIFT          =    4.5665E+06       MODES STILL NEEDED  =         0
0*** USER INFORMATION MESSAGE 4158---STATISTICS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK SCRATCH  FOLLOW
          NUMBER OF NEGATIVE TERMS ON FACTOR DIAGONAL =      1
0*** USER INFORMATION MESSAGE 5010, STURM SEQUENCE DATA FOR EIGENVALUE EXTRACTION.
     TRIAL EIGENVALUE =  4.566476E+06, CYCLES =  3.401032E+02 NUMBER OF EIGENVALUES BELOW THIS VALUE =     1

     END OF LANCZOS RUN
         WARNING FLAG          =        0
         NO. OF MODES COMPUTED =        1

     COMPUTED MODES
             3.76176853986762E+06
 1    TPS RESULTS ANALYSIS                                                      MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    45

 0
 0

                    E I G E N V A L U E  A N A L Y S I S  S U M M A R Y  (LANCZOS ITERATION)


                              BLOCK SIZE USED ......................    2

                              NUMBER OF DECOMPOSITIONS .............    2

                              NUMBER OF ROOTS FOUND ................    1

                              NUMBER OF SOLVES REQUIRED ............    8

                              TERMINATION MESSAGE :  REQUIRED NUMBER OF EIGENVALUES FOUND.
 1    TPS RESULTS ANALYSIS                                                      MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    46

 0

                                            R E A L  E I G E N V A L U E S
   MODE    EXTRACTION      EIGENVALUE            RADIANS            CYCLES           GENERALIZED         GENERALIZED
    NO.       ORDER                                                                      MASS             STIFFNESS
      1          1        3.761769E+06        1.939528E+03        3.086855E+02        1.000000E+00        3.761769E+06
 1    TPS RESULTS ANALYSIS                                                      MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    47
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0
0*** USER INFORMATION MESSAGE 5222 ,UNCOUPLED SOLUTION ALGORITHM USED.
1    TPS RESULTS ANALYSIS                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    48

0
 ***THIS IS MODE #            1
 ***(09-22-92)KNT=            4LMODES=         1
 ***NO. OF COLUMNS=           1
1    TPS RESULTS ANALYSIS                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    49

0
 ***OSTR2(09-14-92)=             -1
1    TPS RESULTS ANALYSIS                                              MARCH  29, 1993  MSC/NASTRAN   7/29/92   PAGE    50

0
0                          X Y - O U T P U T  S U M M A R Y  ( A U T O  O R  P S D F )
0 PLOT  CURVE FRAME                        RMS        NO. POSITIVE  XMIN FOR   XMAX FOR   YMIN FOR    X FOR     YMAX FOR    X FOR*
  TYPE   TYPE  NO.    CURVE ID.           VALUE        CROSSINGS   ALL DATA   ALL DATA   ALL DATA    YMIN     ALL DATA    YMAX
0 PSDF DISP     6       41( 5)     8.917860E-02  3.084809E+02  1.000E-01  1.500E+03  3.207E-10  1.500E+03  1.526E-03  3.091E+02
 ***RMSDIS1=     8.917860E-0225=   8.917860E-02
 ***MODES=        410
 ***MODENO CON1 MODEDIS=      41       243 -1.000000E+00
 ***FREQUENCY=    3.084809E+02
 ***RMSDIS1=      8.917860E-02
 ***THE RMS DIS. AT POINT          41 IS   8.917860E-02 WITH TOTAL OF           1 MODES
 ***LOCALMAX=     1.954125E-02 LOCALMIN=    8.917860E-02
 ***THE MAX RMS DIS. IS   8.917860E-02
0*** USER INFORMATION MESSAGE 4110 (OUTPX2)END-OF-DATA SIMULATION ON FORTRAN UNIT 12
                              (MAXIMUM SIZE OF FORTRAN RECORDS WRITTEN =      1 WORDS.)
                                   (NUMBER OF FORTRAN RECORDS WRITTEN =      1 RECORDS.)
                                   (TOTAL DATA WRITTEN FOR EOF MARKER =      1 WORDS.)
 *** ITERATION NO.(-1=LINEAR)=        4 XNORM=   1.628544E-03
 ***UGNIMAX=      9.011798E-02
 ***MUGNIMAX=     8.917860E-02
 ***ABSOLUTE NORM =    1.053379E-02
0*** USER INFORMATION MESSAGE 4109 (OUTPX2)  THE LABEL IS PDALABEL FOR FORTRAN UNIT 12
                              (MAXIMUM SIZE OF FORTRAN RECORDS WRITTEN =        7 WORDS.)
                                   (NUMBER OF FORTRAN RECORDS WRITTEN =        8 RECORDS.)
                                   (TOTAL DATA WRITTEN FOR TAPE LABEL =       17 WORDS.)
0*** USER INFORMATION MESSAGE 4114 (OUTPX2)
     DATA BLOCK OUGV1PAT WRITTEN ON FORTRAN UNIT 12, TRL =
             101                0              648              0              0              0              0
                                (MAXIMUM POSSIBLE FORTRAN RECORD SIZE =    24576 WORDS.)
                              (MAXIMUM SIZE OF FORTRAN RECORDS WRITTEN =      648 WORDS.)
                                   (NUMBER OF FORTRAN RECORDS WRITTEN =       24 RECORDS.)
                                   (TOTAL DATA WRITTEN FOR DATA BLOCK =      829 WORDS.)
0*** USER INFORMATION MESSAGE 4110 (OUTPX2)END-OF-DATA SIMULATION ON FORTRAN UNIT 12
                              (MAXIMUM SIZE OF FORTRAN RECORDS WRITTEN =      1 WORDS.)
                                   (NUMBER OF FORTRAN RECORDS WRITTEN =      1 RECORDS.)
                                   (TOTAL DATA WRITTEN FOR EOF MARKER =      1 WORDS.)
1                                    * * * END OF JOB * * *
```

Overall Rms Displacements

When the overall rms displacements are requested, DISP=ALL is required in the Control Deck. The overall rms displacement is formed by multiplying the maximum rms displacement by the updated mode shape. The overall rms displacement can be found in the *.f06 output file. It also can be extracted from an OUTPUT2 file by including a "PARAM,POST,-1" card in either the Case Control or Bulk Data Decks.

5.4 Static and Nonlinear Random Analysis

The modified MSC/NASTRAN SEMELRR solution sequence can be combined with other solution sequences to handle the effect of static mechanical and thermal loads on the nonlinear random response. An example is shown for a hexagonal thermal protection system panel subjected to combined thermal and random acoustic loads. The deformed shape due to the static thermal load is first obtained using the SOL 101 procedure. A RESTART of the SEMELRR solution sequence is then run to obtain the dynamic response due to the combined load. The results shown were obtained by post-processing the output with PDA Patran [20].

SOL 101 data cards

```
$      The dimension of the isotropic plate is 15 * 12 * 0.04
$      For the applied thermal load, run tr806-1.dat first,
$      then RESTART on tr806-2.dat
$      IN ORDER TO GET THE COMBINED THERMAL AND ACOUSTIC LOADINGS
$
$      File name : P101.dat
$
$      BUCK DATA is in the PLATE.BDF
$
ID MSC, CHIANG
TIME 100 $
SOL 101 $
CEND $
$
 TITLE = TPS RESULTS ANALYSIS
 SUPER = ALL
 METHOD = 4
 LOAD = 200
    NLPARM = 10
$
ECHO=NONE $
SPC=56 $
BEGIN BULK $
INCLUDE PLATE.BDF
$-------2-------3-------4-------5-------6-------7-------8-------9-------0-------
NLPARM  10      1                       AUTO    1               PW      YES
$-------2-------3-------4-------5-------6-------7-------8-------9-------0-------
PLOAD2  200     1.      1       THRU    64
EIGRL   4       0.01                    8
$-------2-------3-------4-------5-------6-------7-------8-------9-------0-------
PARAM   COUPMASS1
PARAM   NMLOOP  1
PARAM   K6ROT   100.
PARAM   LMODES  1
PARAM   NOCOMPS -1
PARAM   AUTOSPC YES
ENDDATA
```

In order to run SEMELRR with the data base stored from SOL 101, the following command is needed:

nastran P111.dat dbs=P101

SEMELRR data cards

```
RESTART VERSION=1,KEEP $
$
$  File name : P111.dat
$
$  THIS IS THE MODIFIED NASTRAN RANDOM RESPONSE SOLUTION SEQUENCE
$
ACQUIRE MDDL
$
ID CHIANG,NASTRAN
$
COMPILE SEMELRR SOUOUT=USRSOU OBJOUT=USROBJ NOLIST NOREF
INCLUDE SEMELRR.DMAP
COMPILE SEDRCVR SOUOUT=USRSOU OBJOUT=USROBJ NOLIST NOREF
INCLUDE SEDRCVR.DMAP
COMPILE SUPER3  SOUOUT=USRSOU OBJOUT=USROBJ NOLIST NOREF
INCLUDE SUPER3.DMAP
COMPILE SUBDMAP=SEMG SOUIN=MSCSOU NOLIST NOREF $
ALTER 32 $
    EQUIVX EST/ESTL/ALWAYS $
ENDALTER $
SOL SEMELRR  $
LINK SEMELRR $
TIME 100 $
CEND
TITLE = PLATE RESULTS ANALYSIS
SET 1 = 1 THRU 64
DISP =ALL $
STRAIN(FIBER) = 1 $
ECHO = NONE $
METHOD = 4 $
SPC=56
    SDAMP = 102 $
    DLOAD = 301 $
       LOADSET = 500 $
    FREQ  = 3 $
    RANDOM=59 $
$
OUTPUT(XYOUT)
XYPLOT DISP PSDF/ 41(T3)
$
BEGIN BULK $
$-------2-------3-------4-------5-------6-------7-------8-------9-------0-------
```

```
$ FREQUENCY RESPONSE INPUT
$-------2-------3-------4-------5-------6-------7-------8-------9-------0-------
FREQ1   3       0.00    2.      300
DLOAD   301     1.0     1.0     204
RLOAD1  204     300                     10
LSEQ    500     300     100
PLOAD2  100     1.      1       THRU    64
$
TABLED1 10                                                              +QR
+QR     0.0     1.0     2000.0  1.0     ENDT
$
RANDPS  59      1       1       1.0             63
TABRND1 63                                                              +TR
+TR     -1.0    0.0     0.0     8.4215-52000.0  8.4215-52000.0  0.0     +TR2
+TR2    2001.0  0.0     ENDT
$
TABDMP1 102                                                             +DP1
+DP1    0.0     0.04    2000.0  0.04    ENDT
$
PARAM,RMSTRAIN,1 $ IF RMS STRAIN IS NEEDED RMSTRAIN=1
PARAM,MAXITER,3 $ MAX. NUMBER OF ITERATION
PARAM,ABSNORM,2.0E-2 $ ABS. NORM FOR CONVERGE TEST
PARAM,BETA,0.5 $ SCALE FOR BETTER CONVERGENCE, RANGE FROM 0.0 TO 1.0
PARAM,LGDISP,1
$
ENDDATA
$
```

Hexagonal Panel

A hexagonal thermal protection system (TPS) panel similar to the cutout shown in figure 1 was subjected to both thermal and acoustic loads. The structure is composed of an eight-ply carbon-carbon TPS panel with built-up substructure. The TPS panel is connected to the substructure with seven titanium rods (posts). The substructure has an aluminum core sandwiched between an aluminum and a graphite/epoxy face sheet. The dimensions of the panel are given in Table 1, and the finite element mesh is shown in figure 9. The finite element model is comprised of 804 triangular elements and seven bar elements with a total of 622 nodes.

The boundary conditions imposed on the panel were designed to minimize thermal stresses, and are summarized for each component. The edges of the TPS panel are constrained in the perpendicular and tangential directions. The edges of the substructure are constrained in all rotations and translations. The post connections to the TPS panel were modeled as pinned joints using MPC Bulk Data cards. The three translations at the top of the posts were equivalent to the three translations at the adjoining locations of the TPS panel. The connections between the posts and the substructure were also modeled using MPCs. The center post connection was modeled as a rigid link, i.e. all three translations and the two rotations at the lower-end node of the post were equivalent to the translation and rotations of the adjoining node of the substructure. The remaining post connections to the substructure were also modeled as pin joints.

Table 1 Dimensions for hexagonal TPS panel example problem

Radius	13.0 in.
Overall height	2.5 in.
Radius to posts	8.0 in.
Carbon-carbon thickness	0.091 in.
Substructure thickness	0.375 in.

Center post radius	0.1875 in.
Outer post radii	0.125 in.

A 2000 °F temperature load was applied to the TPS panel and a 200 °F load was applied to the posts and substructure. The thermal displacements and stresses were predicted using SOL 101, and are plotted in figures 10 and 11. The TPS panel results are essentially those of a stress-free thermal expansion while the substructure shows a moderate compressive thermal stress with little thermal displacement. The equivalent linearization solution sequence was restarted using the data base from the static thermal solution with the initial stresses and displacements. The rms thermal-acoustic displacements and stresses were predicted for a broadband acoustic excitation of 150 dB uniformly distributed over the carbon-carbon panel. These rms displacements and stresses are plotted in figures 12 and 13. The solution sequence converged in four iterations with the convergence enhancement parameter BETA set to 0.5 and the default convergence criteria.

The level of nonlinearity in the response is typically measured in several ways. The two most common are the ratio of the equivalent linear fundamental frequency to the linear fundamental frequency (frequency ratio) and the ratio of the equivalent linear maximum rms displacement to the linear maximum displacement (amplitude ratio). For this particular problem, these ratios were 1.19 and 0.414, respectively, and are typical of moderate to extreme geometric nonlinearity.

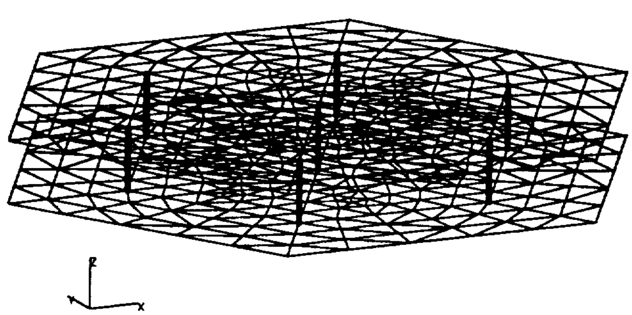

Figure 9: Finite element model

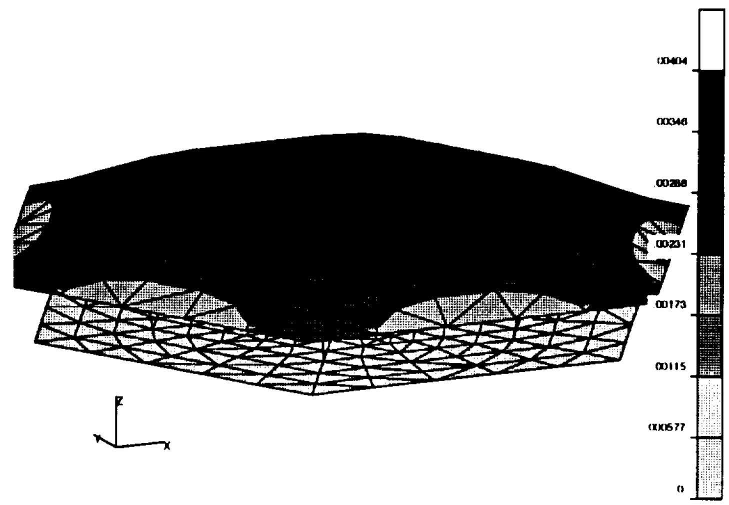

Figure 10: Deformed plot of the thermal displacement vector. Displacements are given in inches.

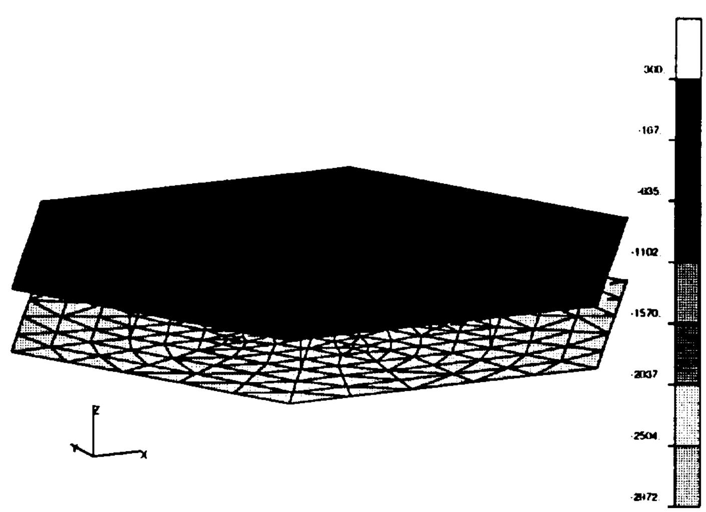

Figure 11: Thermal stresses in the radial direction ϵ_r in psi.

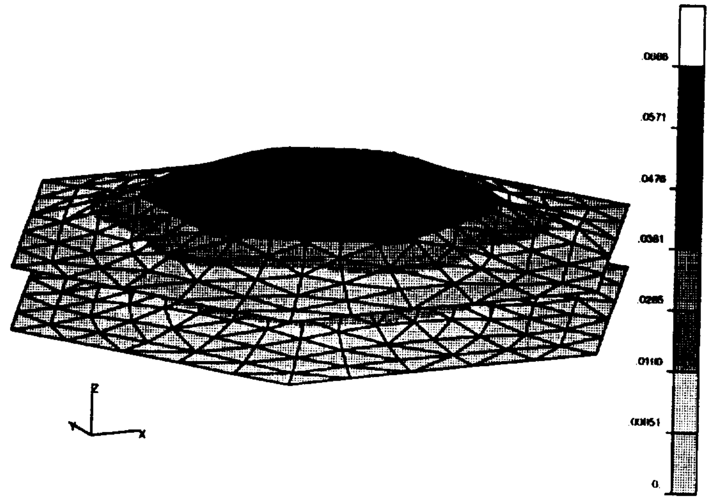

Figure 12: Deformed plot of the root-mean-square thermal-acoustic displacement vector. Displacements are given in inches.

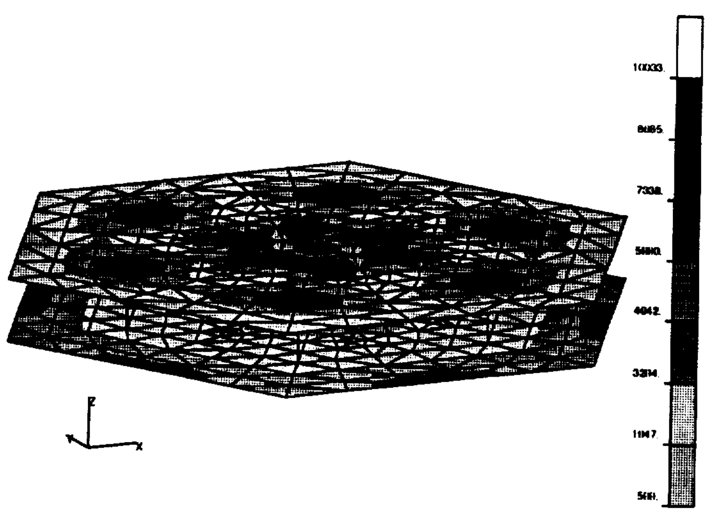

Figure 13: Root-mean-square thermal-acoustic stresses in the radial direction ϵ_r in psi.

Summary

An equivalent linearization solution sequence used to predict the nonlinear random response of structures has been incorporated into MSC/NASTRAN version 67r2. A new main SUBDMAP, SEMELRR, and a significantly modified MSC/NASTRAN SUBDMAP SEDRCVR are compiled with the MSC/NASTRAN delivered library of SUBDMAPs to create the new solution sequence.

The equivalent linear rms displacements, strains or stresses, and frequencies are calculated by an iterative solution method. The numerical results obtained were in good agreement with existing solutions. The output requests and the iterative solution method are controlled by several new user defined PARAMeters. The versatility of the implementation will enable the analyst to determine the nonlinear random responses for complex structures under combined loads.

Acknowledgment

The work presented in this report was performed under the NASP Government Work Package No. 70 (Acoustics and Sonic Fatigue). Dr. Stephen A. Rizzi was the principal investigator for the NASA Langley Research Center portion of the work package and Mr. Kenneth R. Wentz was the principal investigator at Wright Laboratories. Wright Laboratories was the lead center for GWP No. 70.

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Appendix A Main SUBDMAP

```
SUBDMAP SEMELRR $ FROM SOL 111 - SUPERELEMENT MODAL FREQUENCY
$
$  PHASE 1
TYPE DB,KJJ,MJJ,BJJ,USET,GOA,GOAT,KAA,DYNAMICS,KGG,DEQATN,DEQIND,AGG,
        GPLS,SILS,SLT,DM,CASES,EQEXINS,MATPOOL,GM,LOO,KOO,PCDBS,
        DIT,BGPDTS,CSTMS,EST,MPTS,XYCDBS,LLL,KLL,ULL,
        EMAP,MAPS,ETT,PVTS,KFS,KSS,KSF,KVV,EDT,
        GEOM2S,GEOM3S,ECTS,EPTS,INDTA,KELM,KDICT,SLIST,
        GPECT,VELEM,EQEXINX,ECTX,BGPDTX,SILX,GEOM4S,VGFS,MPT,DIT,CSTM,
$      STATIC LOAD GENERATION
        PJ,PTELEM,PG,PA,YS,QR,POS,PSS,PL,
$      DYNAMICS ONLY (SEDR)
        BGG,K4GG,MFF,MLR,MLL,MRR,CMLAMA,CMPHA,CMPHO,MLAA1,
        MR,GOAQ,KLAA,MLAA,MAA,MAR,MRA,BAA,K4AA,MGG,
$  PHASE 2
        PHA,LAMA,CMDD,CK2DD,CB2DD,PHDH,K4DD,VPHFS,
        ULF,ESTNL,UGNI,ESTL,
        PHFA,LAMAF,PHSA,USETNL,PGNI,
$  PHASE 3
        QPF,PUG,UPF,
        OUPF1,OPPF1,OQPF1,OFEF1,OFES1,OFEE1,
        OUPF2,OPPF2,OQPF2,OFEF2,OFES2,OFEE2,GPDTS,
$  DYNAMIC SENSITIVITY
        ULFDS,UPFDS,QPFDS,
$  EQUIV SCRATCH AND DBXSEDR
        BFHH,FLMODPF,FMPF,FOL1,FOL2,GMD,GOD,EDOMX,CASEDR,XYCDBDR,
        KFHH,LDMODPF,LMPF,MFHH,MKAA,MMAA,OA,PCDB,ABEH,
        PFHF,PHFA1,PMPF,PNLMODPF,PPF1,SMPF,STMODPF,UHF1,
        UHFF,UHFS,XYCDB,ABEHX,PHSAF,PHFAS,MUGNI,USET1,
        KDDD,KDJJ,KRDD $
TYPE DB,ZUZR01,ZUZR02,ZUZR03,ZUZR04,ZUZR05,
        ZUZR06,ZUZR07,ZUZR08,ZUZR09,ZUZR10,ZUZR11 $
TYPE DB,ZUZR12,ZUZR13,ZUZR14 $
$ SAVED PARAMETERS
TYPE PARM,NDDL,I,N,LANGLES $
TYPE PARM,NDDL,I,N,LUSETS,KNNLK,FMODE,MPNFLG $
TYPE PARM,NDDL,LOGICAL,N,GOPH2,SKIPSE $
TYPE PARM,,LOGICAL,N,RSTRT $
TYPE PARM,NDDL,CHAR8,N,PANAME $
$ QUALIFERS
TYPE PARM,NDDL,I,N,SEID,NTEMP,LOAD,TEMPLD,DEFORM,MPC,SPC,PEID,METH,
       NLOOP,DESITER,DYRD,MFLUID,METHF,TPL,DLOAD,FREQ,SDAMP,IPANEL   $
TYPE PARM,NDDL,CHAR8,N,K2GG,M2GG,B2GG,P2G,K2PP,M2PP,B2PP,APRCH $
TYPE PARM,NDDL,LOGICAL,N,FSCOUP $
$ USER PARAMETERS
TYPE PARM,,RS,Y,K6ROT=0. $
TYPE PARM,,CHAR8,Y,AUTOSPC='YES    ',DYNSEN='NO' $
TYPE PARM,NDDL,CHAR8,Y,DBXSEDR $
TYPE PARM,NDDL,I,Y,ASING,DDRMM,LMODES,KDAMP,COUPMASS,
                  MODACC,DBDICT,DBDRPRJ,DBDRVER,DBDROPT,EXTRCV,
$           ACOUSTIC ANALYSIS
                  FLUIDMP,STRUCTMP,PANELMP,error $
TYPE PARM,NDDL,RS,Y,G,LFREQ,HFREQ,WTMASS $
$ LOCAL PARAMETERS
TYPE PARM,,CHAR8,N,SUBDMAP='NLSEMFREQ ',APP='FREQRESP',APP1='FREQRESP',
                SOLTYP='MODAL   ' $
TYPE PARM,,LOGICAL,N,RSONLY=FALSE,FS=FALSE,NOPH2=FALSE,DOPH2M=TRUE $
TYPE PARM,,I,N,DMAPNO=211,PFILE=0,CARDNO=0,LASTSEID,DROPT=0,
               NOUSET,NOASET,NOBSET,NOCSET,NOGSET,NOLSET,NOOSET,NOQSET,
               NORSET,NOSSET,NOTSET,NOVSET,NOA,NOSET,NORC,NOMSET,
               NOSASET,NOFASET=0,NSEIG,NFEIG,NFSEIG,LMODEX,
               IFREQ,IFREQX,NOOG,USETABS,NBMP=-1,NEWK=-1,NOKGGNL,
               SOLCUR,SOLPRE,UNVPABS $
TYPE PARM,NDDL,RS,Y,EPPRT,EPZERO,MAXRATIO,PRPA,PRPJ,
                 EPSNALU,EPSMALC,EPSBIG,EPSRC,PRPHIVZ,RMAX,SIGMA,
                 TINY,TABS $
TYPE PARM,NDDL,I,Y,SEQOUT,NEWSEQ,SUPER,FACTOR,MPCX,START,
                IRES,GRDPNT,SPCGEN,GPECT,EST,USETPRT,USETSEL,
                BAILOUT,INRLM,PRTPCH,MPECI,NOSHADE,
                GEOMU,LOADU,POSTU,DBCDIAG,FIXEDB,LGDISP $
TYPE PARM,NDDL,CS,Y,CM1,CM2,CK1,CK2,CK3,CB1,CB2,CP1,CP2 $
TYPE PARM,NDDL,CHAR8,Y,PRGPST,DBCCONV,DBCOVWRT $
TYPE PARM,,I,Y,KNT=-1,LOOPID=0,SLOOPID=-1,RMSTRAIN,MAXITER=5 $
TYPE PARM,,I,N,NSKIP=0 $
TYPE PARM,,RS,N,OFREQ,XNORM=1.0 $
TYPE PARM,,RS,Y,BETA=0.5,ABSNORM=0.05,MAXNORM=1.0-3 $
TYPE PARM,,RS,N,UGNIMAX,MUGNIMAX,23,24 $
TYPE PARM,,CS,N,GAMMA=(1.0,0.0),OMEGA2,IOMEGA $
TYPE PARM,,CS,N,CONST1=(1.0,0.0),CONST2=(1.0,0.0) $
$
$ ----------- PERFORM PHASE 0 AND I OPERATIONS
$
NLOOP=0  $ SET QUALIFIER
CALL SUPER1  /CASECC,USET,GOAT,KAA,DYNAMICS,GPLS,SILS,SLT,DM,
             CASES,EQEXINS,MATPOOL,GM,DIT,BGPDTS,CSTMS,EST,MPTS,
             XYCDBS,LLL,KLL,ULL,,PCDB,EMAP,XYCDB,MAPS,ETT,PVTS,
             KFS,KSS,KSF,EDT,EDOMX,GEOM2S,GEOM3S,POSTCDB,ECTS,EPTS,
             INDTA,KELM,KDICT,GPECT,VELEM,FORCE,EQEXINX,ECTX,BGPDTX,
             SILX,,,PJ,PTELEM,PG,PA,YS,QR,POS,PSS,PL,,
             ,KVV,KJJ,KGG,KOO,LOO,BJJ,BGG,K4GG,MJJ,MFF,MLR,
             MLL,MRR,CMLAMA,CMPHA,CMPHO,MLAA1,MR,GOAQ,KLAA,MLAA,MAA,
             MAR,MRA,BAA,K4AA,MGG,,,,,GEOM4S,VGFS,
             PCDBS,ESTL,ESTNL,AGG,DMI,DMINDX,DTI,DTINDX,DEQATN,DEQIND,
             KDMIT,EQIDMO,PLIST2,PLIST3,CONSBL,DPLDXI,DXDMIT,
             DTOS2,DTOS3,DTOS4,DSCREN,TABDEQ,DVP,DVTM,DTB,
             DBQCON,DBQPOS,DBSGRD,DBSGID,COORDM,DCLDXT,CON/
             APP/DMAPNO/S,RSONLY/SOLTYP/FALSE/FALSE/FALSE/TRUE/
             APRCH/S,SEID/S,PEID/S,NTEMP/S,LOAD/S,TEMPLD/S,DEFORM/
             S,MPC/S,SPC/S,K2GG/S,M2GG/S,B2GG/S,P2G/S,DYRD/S,METH/
             S,MFLUID/S,LASTSEID/S,PFILE/S,LUSETS/S,FSCOUP/K6ROT/
             AUTOSPC/S,NOPH2/S,DOPH2M/S,DESITER $
DO WHILE( KNT<=MAXITER ) $
IF ( EXTRCV=0 ) THEN $
$
$ ----------- PERFORM PHASE II OPERATIONS
$
PUTSYS(0,109) $ FORCE EXECUTION ON RESTART
PUTSYS(0,82) $ DISALLOWS DMAP TO FIELD NOGO FLAGS
FILE       DLT=SAVE,OVRWRT/VAFS=SAVE,OVRWRT/LAMAS=SAVE,OVRWRT/
           MHH=SAVE,OVRWRT/BHH=SAVE,OVRWRT/KHH=SAVE,OVRWRT/
           PPF=SAVE,OVRWRT/PSF=SAVE,OVRWRT/PDF=SAVE,OVRWRT/
           FOL=SAVE,OVRWRT/PHF=SAVE,OVRWRT/UHF=SAVE,OVRWRT/
           CASEDR=SAVE/XYCDBDR=SAVE,OVRWRT/UPF=SAVE,OVRWRT/
           MKAA=SAVE,OVRWRT/CSTMS=SAVE,OVRWRT/KDGG=SAVE,OVRWRT/
           USET=SAVE,OVRWRT $
FILE       KLAA=SAVE,OVRWRT/MLAA=SAVE,OVRWRT $
FILE       KELMNL=SAVE,OVRWRT/KDICTNL=SAVE,OVRWRT $
FILE       MUGNI=SAVE,OVRWRT/MESTNL=SAVE,OVRWRT/ESTNL=SAVE,OVRWRT $
FILE       EST=SAVE,OVRWRT/ESTL=SAVE,OVRWRT/UGNI=SAVE,OVRWRT $
FILE       CASESX2H=SAVE $
FILE       ZUZR13=OVRWRT/ZUZR14=OVRWRT/ZUZR15=OVRWRT $
FILE       KAA=SAVE,OVRWRT/MAA=SAVE,OVRWRT/GPECT=SAVE,OVRWRT $
$
$  NONLINEAR OUTPUTS
$
IF ( NOT GOPH2 ) CALL ERRPH2  //'PHASE I'/0  $  ERROR IN PHASE I
PARAML   CASECC//'DTI'/1/208//S,N,MANUAL $ FLAG FOR MANUAL RESTARTS
IF ( MANUAL<>-1 AND LASTSEID<>0 ) EXIT  $  EVERYTHING IS OK
$        IN PHASE I BUT USER MADE NO PHASE I REQUESTS FOR R.S.
$        AND REQUESTED MANUAL ANALYSIS ONLY
$
$   PERFORM EIGENSOLUTION ON RESIDUAL STRUCTURE
$
CALL PMLUSET  USET//S,NOASET/S,NOBSET/S,NOCSET/S,NOGSET/S,NOLSET/
                    S,NOOSET/S,NOQSET/S,NORSET/S,NOSSET/S,NOTSET/
                    S,NOVSET/S,NOA/S,NOSET/S,NORC/S,NOMSET/S,NOUSET $
IF ( NOUSET=-1 ) THEN $
   MESSAGE   //' DMAP FATAL MESSAGE 9015 (NLSEMFREQ) -'/
                ' THE USET TABLE IS NOT PRESENT.' $
ENDIF $
$
DBXSEDR=DBXSEDR $ SET LOCATION FOR DATABLOCKS NEEDED FOR EXTERNAL SE DR
$      SET UP TABLES FOR DYNAMIC ANALYSIS - UM 3.3.24
DPD        DYNAMICS  ,GPLS,SILS,USET,SLT,PG/GPLD,SILD,USETD,
           TFPOOL,DLT,PSDL,FRL,NLFT,TRL,EED,EQDYN/-1/S,N,LUSETD/
           0/0/0/0/0/   0   /  1   /123/S,N,NOUE $
$
PARAML   CASES//'DTI'/1/ 15//  S,N,TPL $
PARAML   CASES//'DTI'/1/139////S,N,K2PPA $
PARAML   CASES//'DTI'/1/140////S,N,K2PPB $
K2PP=K2PPA & K2PPB
PARAML   CASES//'DTI'/1/141////S,N,M2PPA $
PARAML   CASES//'DTI'/1/142////S,N,M2PPB $
M2PP=M2PPA & M2PPB
PARAML   CASES//'DTI'/1/143////S,N,B2PPA $
PARAML   CASES//'DTI'/1/144////S,N,B2PPB $
B2PP=B2PPA & B2PPB
PARAML   CASES//'DTI'/1/149//S,N,SDAMP $
PARAML   CASES//'DTI'/1/13 //S,N,DLOAD $
PARAML   CASES//'DTI'/1/14 //S,N,FREQ $
PARAML   CASES//'DTI'/1/226//S,N,METHF $ METHOD(FLUID)
$
PARAML   VGFS//'PRES'////S,N,NOVGFS $
IF ( NOVGFS>-1 ) THEN $
   EQUIVX   VGFS/VAFS/NOA $
   IF (NOA>-1) UPARTN   USET,VGFS/VAFS.../'G'/'A'/'S'/1 $
   PARAML   VAFS//'TRAILER'/5/S,N,NOFASET $
   PARAML   VAFS//'TRAILER'/4/S,N,PREC $
   NOFASET=NOFASET/PREC $       NO. OF FLUID      DOFS IN A-SET
ENDIF $
NOSASET=NOASET-NOFASET $        NO. OF STRUCTURE DOFS IN A-SET
FS=(NOSASET>0 AND NOFASET>0) $ BOTH FLUID AND STRUCTURE EXIST
$
IF ( NOT NOPH2 ) THEN $
$
$      COMBINE STATIC AND DYNAMIC PORTION OF THE RESIDUAL STRUCTURE
$
CALL SEGOA  GOAT/GOA /NOOSET/NOQSET/NOTSET $ TRANSFORMATION
IF ( NOQSET=-1 ) THEN $
   EQUIVX    KAA/MKAA/ALWAYS $
ELSE IF ( NOTSET=-1 ) THEN $
   EQUIVX    KLAA/MKAA/ALWAYS $
ELSE $
   ADD5      KAA,KLAA.../MKAA $
ENDIF $
ADD5      MLAA,MAA.../MMAA $
$
EQUIVX   GOA/GOD/NOUE $
EQUIVX   GM/GMD/NOUE $
EQUIVX   K4AA/K4DD/NOUE $
IF ( NOUE>-1 ) THEN $
   UMERGE1  USETD,GM.../GMD/'NE'/'N'/'E'/2 $
   UMERGE1  USETD,GOA.../GOD/'D'/'A'/'E'/2 $
   UMERGE1  USETD,K4AA.../K4DD/'D'/'A'/'E' $
ENDIF $
DBVIEW KESTNL = ESTNL (WHERE NLOOP = SLOOPID) $
```

```
DBVIEW YUGNI   = MUGNI   (WHERE NLOOP = SLOOPID) $
DBVIEW YPGNI   = PGNI   (WHERE NLOOP = SLOOPID) $
DBVIEW YESTNL = ESTNL (WHERE NLOOP = LOOPID) $
$
$ INITIALIZE SOLPRE AND SOLCUR
SOLPRE=LOOPID $
SOLCUR=SOLPRE $
RSTRT=(LOOPID>0) $ LOOPID=0 FOR COLD START AND >0 FOR RESTART
   PARAML   YUGNI//'PRES'////S,N,NOYUGNI $
   IF ( NOYUGNI>-1 ) THEN $
      NLOOP=0 $
      EQUIVX   YUGNI/ULX/NOA $
      EQUIVX   YPGNI/PLX/NOA $
      IF ( NOA>-1 ) THEN $
         UPARTN   USET,YUGNI/ULX,,,/'G'/'A'/'S'/1 $
         SSG2     USET,GM,,KFS,GOA,DM,YPGNI/,,,PAX,PLX $
      ENDIF $ NOA>-1
      EQUIVX   ULX/ULNTI/ALWAYS $
      EQUIVX   PLX/IFD/ALWAYS $
      COPY     IFD/IFDH $
      COPY     ULNTI/ULNTH $
   ENDIF $ NOYUGNI>-1
 DELETE /MESTNL,,,, $
COPY  YESTNL/MESTNL $
DBVIEW GM0=GM (WHERE NLOOP=0) $
DBVIEW KDD0=MKAA (WHERE NLOOP=0) $
$
$  IF THERE IS NO EXTRA POINT, A-SET = D-SET
$
DBVIEW USET0=USET (WHERE NLOOP=0) $
$
IF ( KNT>-1) THEN $
$
$     TOP OF NON-LINEAR LOOP
$
   SOLCUR=SOLPRE+1 $
   NLOOP=SOLCUR-1 $
$
$  FIND KOG FOR NONLINEAR ELEMENTS; ALSO KDGG IF GEOM NONLINEAR
$  REDUCE THESE TO A-SIZE
$
   EQUIVX KDD0/KAA/ALWAYS $
   IF ( LGDISP>-1 ) THEN $ FOR GEOMETRIC NONLINEAR
$                            GENERATE KDJJ AND REDUCE TO KDDD
$
      IF ( UNVFABS>-1 ) THEN $ JUMP ONLY FOR COLD START W/O IC
$        EXTRACT AND FORM ULNI FROM ULNTI
         PARAML   ULNTH//'TRAILER'/1/S,N,DCOL $ DCOL'S IN ULNTI
         IF ( DCOL<2 ) THEN $
            EQUIVX   ULNTH/ULNTX/ALWAYS $
         ELSE $
            IF ( NEWP>-1 ) DCOL=DCOL-1 $ SUBTRACT TO BACK UP FOR ACCEL
            DCOL=DCOL-1 $ NOW DCOL CORRESPONDS TO DISPL
$            EXTRACT DCOL-TH COLUMN VECTOR
            MATMOD   ULNTH...../ULNTX,/1/DCOL $
         ENDIF $ DCOL<2
         EQUIVX   ULNTX/ULNX/ALWAYS $
         SDR1     USET,,ULNX,,,GOA,GM0,,,,/ULNIX,,/1/'FREQ' $
$
$  END OF FORMING DISPL VECTOR FOR K MATRIX
$
      CASE      CASECC,/CASEXX/'FREQ'/S,N,REPEAT/0 $
      VECPLOT  MUGNI,ZUZR11,EQEXINS,CSTMS,CASEXX,/UGVBAS/0/0/3  $
      EQUIVX BGPDTS/ZUZR10/ALWAYS $
      DELETE /BGPDTS,,,, $
      MATMOD UGVBAS,ZUZR10,,,,/BGPDTS,/11 $
      DELETE /ESTNL,EST,,, $
      TA1        MPTS,ECTS,EPTS,BGPDTS,SILS,ETT,CSTMS,DIT/
                 EST,ESTNL,GEI,GPECT,ESTL/
                 LUSETS/1/S,N,NOSIMP/2/S,N,NOGENL/SEID/
                 1/NLAYERS $
      EMG        ESTNL,CSTMS,MPTS,DIT,,ULNIX,,/KDELMH,KDDICTH,,,,/
        -           1/0/0////////////////LANGLES $
      EMA        GPECT,KDDICTH,KDELMH,BGPDTS,SILS,CSTMS/KDJJ,/-1 $
$
$   REDUCE DIFFERENTIAL STIFFNESS AND COMPUTE
$   TANGENTIAL STIFFNESS FOR GEOMETRIC NONLINEAR
$
         EQUIVX   KDJJ/KDNN/NOMSET $
         IF ( NOMSET>-1 ) MCE2      USET0,GM0,KDJJ,,,/KDNN,,, $
         EQUIVX   KDNN/KDFF/NOSSET $
         IF ( NOSSET>-1 ) SCE1      USET0,KDNN,,,/KDFF,,,,, $
         EQUIVX KDFF/KDLL/NOOSET $
         IF ( NOOSET>-1 ) THEN $
$           KOONL MUST BE NULL
            UPARTN   USET0,KDFF/KDLL,,,KDOO/'F'/'A'/'O' $
            PARAML   KDOO//'TRAILER'/5/S,N,ONOTNULL//S,N,NP $
$   ERROR 4423 => NONLINEAR ELEMENT ATTACHED TO OMITTED DOF
            IF ( ONOTNULL>0 ) CALL ERRPH2  //SUBDMAP/4423 $ RPERRM
         ENDIF $ NOOSET>-1
         EQUIVX KDLL/KDDD/ALWAYS $
         EQUIVX KDDD/KBDD/ALWAYS $
      ENDIF $ UNVFABS>-1
   ENDIF $ LGDISP>-1
  ENDIF $ KNT > -1 11/20/91
$
IF ( NOQSET=-1 ) THEN $
   ADDS KAA,KDLL,,,/MKAA//(3.0,0.0) $
ELSE IF ( NOTSET=-1 ) THEN $
   ADDS KLAA,KDLL,,,/MKAA//(3.0,0.0) $
ELSE $
   ADDS      KAA,KLAA,KDLL,,/MKAA///(3.0,0.0) $
ENDIF $
$
IF ( DOPH2M ) delete /pha,lama,phfa,lamaf,phsa $
              delete /lamas,,,, $
               CALL MODEFSRS,
```

```
                    MR,USET,DM,CASES,DYNAMICS,MMAA,MKAA,GPLS,SILS,EED,
                    EQEXINS,VAFS/
                    PHA,LAMA,PHFA,LAMAF,PHSA,LAMAS/
                    NORSET/NOLSET/ASING/NOASET/FS/NOFASET/NOSASET/
                    METH/METHF $
$
IF (METH>0 AND NOSASET>0) THEN $
   IF ( FS ) THEN $
      MERGE     PHSA,,,,,VAFS/PHSAF/1 $
   ELSE $
      EQUIVX    PHSA/PHSAF/-1 $
   ENDIF $
   VDR        CASES,EQEXINS,USET,PHSAF,LAMAS,,/OPHSA,/'REIG'/
              'DIRECT'/0/S,N,NOSVECT/1/1 $
   IF ( NOSVECT > -1 ) OFP        OPHSA//S,N,CARDNO $
$                         SVECTOR OUTPUT FOR RESIDUAL STRUCTURE ONLY
ENDIF $ METH>0 AND NOSASET>0
$
IF (METHF>0 AND NOFASET>0) THEN $
   IF ( FS ) THEN $
      MERGE     ,,PHFA,,,,VAFS/PHFAS/1 $
   ELSE $
      EQUIVX    PHFA/PHFAS/-1 $
   ENDIF $
   VDR        CASES,EQEXINS,USET,PHFAS,LAMAF,,/OPHFA,/'REIG'/
              'DIRECT'/0/S,N,NOSVECT/1/1 $
   IF ( NOSVECT > -1 ) OFP        OPHFA//S,N,CARDNO $
$                         SVECTOR OUTPUT FOR RESIDUAL STRUCTURE ONLY
ENDIF $ METHF<>0 AND NOFASET>0
$
      DELETE    /ESTNL,,,, $
      DELETE   /MHH,BHH,KHH,PHIDH,PHDH/ $
CALL GMA   CASES,MATPOOL,EQDYN,TFPOOL,,,,
           MMAA,GOD,GMD,USETD,MKAA,BAA,K4DD,PHA,LAMA,DIT,VAFS,
           PHSA,PHFA,LAMAS,AGG/
           ,,CMDD,CK2DD,CB2DD,MHH,BHH,KHH,PHDH,VPHFS/
           LUSETD/SOLTYP/APP/NOUE/NOA/G/0./0./TRUE/
           0/LMODES/LFREQ/HFREQ/S,FMODE/KDAMP/FALSE/FALSE/FS $
$
     DELETE /PPF,PSF,PDF,FOL,PHF/ $
     DELETE /UHVF,UHF,,, $ AVOID OUTPUT TWICE
CALL MFREQRS  CASES,USETD,DLT,FRL,GMD,GOD,DIT,PHDH,KHH,BHH,MHH,
              ,,,,,,,,,/
              PPF,PSF,PDF,FOL,PHF,UHF/
              SOLTYP/APP/NOA/FALSE/0./0./0./0 $
$
ENDIF $ NOT (NOPH2)
$
PARAML   UHF//'PRES'////S,N,NOUHF $
IF (NOUHF=-1) EXIT $ IF NO SOLUTION TO PROCESS.
$
PARAML    PHFA//'TRAILER'/1/S,N,NFEIG//S,N,NOPHFA $
PARAML    PHSA//'TRAILER'/1/S,N,NSEIG//S,N,NOPHSA $
IF ( NOPHFA=-1 ) THEN $
   EQUIVX   UHF/UHFS/ALWAYS $
ELSE IF ( NOPHSA=-1 ) THEN $
   EQUIVX   UHF/UHFF/ALWAYS $
ELSE $
$       EXTRACT FLUID AND STRUCTURE SOLUTIONS
   PARTN     UHF,,VPHFS/UHFS,UHFF,,/1 $
ENDIF $
$
IF ( NOPHSA>-1 ) CALL VDR1,
              CASES,EQDYN,USETD,UHFS,FOL,XYCDBS,,PSDL,DIT,//
              APP/SOLTYP/S,CARDNO/S,PFILE/'HSET    '/FMODE/FALSE $
$
IF ( NOPHFA>-1 ) CALL VDR1,
              CASES,EQDYN,USETD,UHFF,FOL,XYCDBS,,PSDL,DIT,//
              APP/SOLTYP/S,CARDNO/S,PFILE/'HSET    '/FMODE/FALSE $
$
IF ( FS ) DDRMM=-1 $
IF ( DDRMM>=0 ) APP1 = 'MMREIG  ' $
$
      DELETE /FOL1,PPF1,ULF,PSF1,UHF1 $ AVOID OUTPUT TWICE
CALL MODACC  CASES,FOL,UHF,PPF,PDF,PSF,PHDH,
             USETD,CK2DD,CB2DD,CMDD,LLL,DM/
             FOL1,PPF1,ULF,PSF1,UHF1/
             APP/APP1/NOUE/MODACC/SOLTYP/FALSE/'NO   ' $
$
$ IF NUMBER OF FREQUENCIES FOR FLUID, FLUIDMP, IS -1 THEN
$    COMPUTE FLUID MODAL PARTICIPATION FOR ALL FREQUENCIES
PARAML    FOL1//'TRAILER'/1/S,N,NOFREQ $
IF ( FLUIDMP<0 OR FLUIDMP>NOFREQ ) FLUIDMP=NOFREQ $
IF ( FLUIDMP>0 ) MESSAGE //
   ' DMAP INFORMATION MESSAGE 9053 (NLSEMFREQ) - FLUID MODAL'/
   ' PARTICIPATION IS REQUESTED FOR'/FLUIDMP/' FREQUENCIES.' $
$ IF NUMBER OF FREQUENCIES FOR STRUCTURE, STRUCTMP, IS -1 THEN
$    COMPUTE STRUCTURAL MODAL PARTICIPATION FOR ALL FREQUENCIES
IF ( STRUCTMP<0 OR STRUCTMP>NOFREQ ) STRUCTMP=NOFREQ $
IF ( STRUCTMP>0 ) MESSAGE //
   ' DMAP INFORMATION MESSAGE 9053 (NLSEMFREQ) - STRUCTURAL AND LOAD'/
   ' MODAL PARTICIPATION IS REQUESTED FOR'/STRUCTMP/' FREQUENCIES.' $
$
IF ( STRUCTMP>0 OR FLUIDMP>0 OR PANELMP>0 ) THEN $
$         COMPUTE MODAL PARTICIPATION IF REQUESTED
$
PARAML   CASES//'DTI'/-1/161//S,N,YESOG $
NOOG=LTOI(NOTL(YESOG)) $
IF ( NOOG>-1 ) MATMOD   EQEXINS,USET,SILS,CASES,,/
                        OG,/17//1/S,N,NOOG $
EQUIVX   VAFS/OA/NOOG $
EQUIVX   PHFA/PHFA1/NOOG $
IF ( NOOG>-1 ) THEN $
   UPARTN   USET,OG/OA,,,/'G'/'A'/'S'/1 $
   PARTN    OA,,VAFS/,OAF,,/1 $
   PARTN    PHFA,,OAF/,PHFA1,,/1 $
ENDIF $
```

```
$
DELETE   /UHPS,UHPF,,, $
IF ( NOPHFA=-1 ) THEN $
   EQUIVX   UHF1/UHPS/ALWAYS $
ELSE IF ( NOPHSA=-1 ) THEN $
   EQUIVX   UHF1/UHPF/ALWAYS $
ELSE $
$      EXTRACT FLUID AND STRUCTURE SOLUTIONS
   PARTN    UHF1,,VPHFS/UHPS,UHPF,,/1 $
ENDIF $
$
IF ( STRUCTMP>0 ) MODACC   CASES,POL,UHF,,PHF,/POLX,UHFX,,PHF1,/APP $
IF ( NOPHSA=-1 AND STRUCTMP>0 ) THEN $
$  RESIDUAL MODES ARE ALL FLUID MODES
   EQUIVX   MHH/MFHH/ALWAYS $
   EQUIVX   KHH/KFHH/ALWAYS $
   EQUIVX   BHH/BFHH/ALWAYS $
   EQUIVX   PHF1/PFHF/ALWAYS $
ELSE IF ( NOPHFA>-1 ) THEN $
$  RESIDUAL MODES ARE BOTH FLUID AND STRUCTURE MODES
   IF ( STRUCTMP>0 ) THEN $ DO THIS ONCE ONLY IF REQUESTED
      PARTN    MHH,VPHFS,/,AH,,MFHH $ EXTRACT COUPLING AND FLUID MASS
      PARTN    KHH,VPHFS,/,,,KFHH $   EXTRACT FLUID STIFFNESS
      PARTN    BHH,VPHFS,/,,,BFHH $   EXTRACT FLUID DAMPING
      PARTN    PHF1,,VPHFS/,PFHF,,/1 $ EXTRACT FLUID LOADS
   ENDIF $ STRUCTMP>0
   IF ( PANELMP>-1 AND MPNFLG>0 ) THEN $
      GPS      ECTS,BGPDTS,EQEXINS,EDT,SILS/
               MPNSLT,MEQAST,MNRTAB/
               MPNFLG/S,N,NUMPAN/S,N,MATCH $
      IPANEL=1 $
      DO WHILE ( IPANEL<=NUMPAN ) $
         ACMG     MPNSLT,BGPDTS,CSTMS,SILS,ECTS,MEQAST,MNRTAB/
                  ABE/LUSETS/MPNFLG/NUMPAN/S,N,PANAME/IPANEL/MATCH $
$        THE ABE MATRIX IS NEGATED BELOW, BY 2ND PARAMETER OF SMPYAD
         MATREDU  ABE,USET,GM,GOA/ABEA/S,N,NOABE $
         PARTN    ABEA,VAFS,/,,ABESF, $
         SMPYAD   PHFA1,ABESF,PHSA,,,/ABEHX/3/-1///1/1 $
         IF ( LMODES>0 AND LMODES<NSEIG ) THEN $
            LMODEX=NSEIG-LMODES $
            MATGEN    ,/LMODES/6/NSEIG/LMODES/LMODEX $
            PARTN     ABEHX,LMODES,/ABEH,,,/1 $
         ELSE $
            EQUIVX    ABEHX/ABEH/-1 $
         ENDIF $
         IPANEL=IPANEL+1 $
      ENDDO $ IPANEL<=NUMPAN
   ENDIF $ PANELMP>-1 AND MPNFLG>0
ENDIF $
$
IFREQ=1 $
DO WHILE ( IFREQ<=FLUIDMP ) $
   MATMOD   UHPF,,,,,/UHPFI,/1/IFREQ $ EXTRACT A COLUMN (FREQUENCY)
   PARAML   UHPFI//'NULL'////S,N,ZUHPI $
   IFREQX=IFREQ+2 $
   PARAML   FOL1//'DTI'/0/IFREQX/S,N,OFREQ $
   IF ( ZUHPI>-1 AND OFREQ>0. ) THEN $
      MATMOD   UHPFI,,,,,/UHPFD,/28 $ DIAGONALIZE COLUMN
      MPYAD    PHFA1,UHPFD,/FMPF $ FLUID MODAL PARTICIPATION
      MESSAGE  //' DMAP INFORMATION MESSAGE 9054 (NLSEMFREQ) -'/
        ' FLUID MODAL PARTICIPATION FACTORS FOR FREQUENCY='/OFREQ/
        ' SHOWN BELOW IN MATRIX FLMODPF' $
$          IF NEEDED, EXPAND TO A-SIZE SO THAT MATGPR UNDERSTANDS
      EQUIVX   FMPF/FLMODPF/NOSASET $
      IF ( NOSASET>-1 ) MERGE     ,,FMPF,,,,OA/FLMODPF/1 $
      MATGPR   GPLS,USET,SILS,FLMODPF//'H'/'A' $
   ENDIF $ ZUHPI>-1 OR OFREQ>0.
   IFREQ=IFREQ+1 $
ENDDO $ IFREQ<=FLUIDMP
$
IFREQ=1 $
DO WHILE ( IFREQ<=STRUCTMP ) $
   MATMOD   UHPS,,,,,/UHPSI,/1/IFREQ $ EXTRACT A COLUMN OF DISPLACEMENT
   MATMOD   PPHF,,,,,/PPHFI,/1/IFREQ $ EXTRACT A COLUMN OF LOAD
   PARAML   UHPSI//'NULL'////S,N,ZUHPI $
   IFREQX=IFREQ+2 $ SET UP POINTER TO FREQUENCY LIST
   PARAML   FOL1//'DTI'/0/IFREQX/S,N,OFREQ $ EXTRACT INPUT FREQUENCY
   IF ( ZUHPI>-1 AND OFREQ>0. ) THEN $
      MATMOD   UHPSI,,,,,/UHPSD,/28 $ DIAGONALIZE COLUMN
      MPYAD    AH,UHPSD,/A1 $ MODAL COUPLING X DIAGONAL COLUMN
$        CONVERT FREQ TO COMPLEX -OMEGA**2
      OMEGA2=CMPLX(-((2.*PI(1)*OFREQ)**2)) $
      IOMEGA=CMPLX(0.,(2.*PI(1)*OFREQ)) $
$        -OMEGA**2(MASS) + I*OMEGA(DAMPING) + STIFFNESS
      ADD5     MFHH,BFHH,KFHH,,/Z2X/OMEGA2/IOMEGA $
      DECOMP   Z2X/Z2L,Z2U/////S,N,SING $ DECOMPOSE Z2X
      IF ( SING>-1 ) THEN $ IF Z2X IS NOT SINGULAR THEN PROCEED
$
$          COMPUTE STRUCTURAL PARTICIPATION
$
         MESSAGE  //' DMAP INFORMATION MESSAGE 9054 (NLSEMFREQ) -'/
           ' STRUCTURAL MODAL PARTICIPATION FACTORS FOR FREQUENCY='/
         OFREQ/' SHOWN BELOW IN MATRIX STMODPF' $
         FBS      Z2L,Z2U,A1/XSMPF $ SOLVE FOR PARTIAL PARTICIPATION
         OMEGA2=-OMEGA2 $ CONVERT OMEGA**2 ABOVE TO POSITIVE
         ADD5     PHFA1,,,,/W2PHFA/OMEGA2 $ OMEGA**2 X FLUID MODES
         MPYAD    W2PHFA,XSMPF,/SMPF $ STRUCTURAL MODAL PARTICIPATION
$         IF NEEDED, EXPAND TO A-SIZE SO THAT MATGPR UNDERSTANDS
         EQUIVX   SMPF/STMODPF/NOFASET $
         IF ( NOFASET>-1 ) MERGE     ,,SMPF,,,,OA/STMODPF/1 $
$           PRINT STMODPF IN EXTERNAL ORDER
         MATGPR   GPLS,USET,SILS,STMODPF//'H'/'A' $
$
$          COMPUTE PANEL PARTICIPATION
$
         IF ( MPNFLG>0 AND PANELMP>-1 ) THEN $
            IPANEL=1 $
```

```
            DO WHILE ( IPANEL<=NUMPAN ) $
               MPYAD    ABEH,UHPSD,/A1P $
               FBS      Z2L,Z2U,A1P/XPMPF $
               MPYAD    W2PHFA,XPMPF,/PMPF $ PANEL MODAL PARTICIPATION
$           IF NEEDED, EXPAND TO A-SIZE SO THAT MATGPR UNDERSTANDS
               EQUIVX   PMPF/PNLMODPF/NOFASET $
               IF ( NOFASET>-1 ) MERGE     ,,PMPF,,,,OA/PNLMODPF/1 $
$             PRINT PNLMODPF IN EXTERNAL ORDER
              MESSAGE  //' DMAP INFORMATION MESSAGE 9054 (NLSEMFREQ) -'/
                 ' PANEL MODAL PARTICIPATION FACTORS FOR PANEL = '/
                 PANAME/' AT FREQUENCY ='/OFREQ/' SHOWN BELOW IN'/
                 ' MATRIX'/' PNLMODPF' $
               MATGPR   GPLS,USET,SILS,PNLMODPF//'H'/'A' $
               IPANEL=IPANEL+1 $
            ENDDO $ IPANEL<=NUMPAN
         ENDIF $ MPNFLG>0 AND PANELMP>-1
$
$           COMPUTE LOAD PARTICIPATION
$
         MESSAGE  //' DMAP INFORMATION MESSAGE 9054 (NLSEMFREQ) -'/
            ' LOAD MODAL PARTICIPATION FACTORS FOR FREQUENCY='/OFREQ/
            ' SHOWN BELOW IN MATRIX LDMODPF' $
         FBS      Z2L,Z2U,PPHFI/XLMPF $ GET THE INTERMEDIATE VECTOR
         MPYAD    PHFA1,XLMPF,/LMPF $
$         IF NEEDED, EXPAND TO A-SIZE SO THAT MATGPR UNDERSTANDS
         EQUIVX   LMPF/LDMODPF/NOFASET $
         IF ( NOFASET>-1 ) MERGE     ,,LMPF,,,,OA/LDMODPF/1 $
$           PRINT LMODPF IN EXTERNAL ORDER
         MATGPR   GPLS,USET,SILS,LDMODPF//'H'/'A' $
      ENDIF $ SING>-1
   ENDIF $ ZUHPI>-1 OR OFREQ>0.
   IFREQ=IFREQ+1 $
ENDDO $ IFREQ<=STRUCTMP
ENDIF $ STRUCTMP>0 OR FLUIDMP>0
ENDIF $ EXTRCV=0
$
$ ----------- PERFORM PHASE III OPERATIONS
$
EQUIVX  FOL1/FOL2/DDRMM $
IF ( DDRMM>=0 ) EQUIVX  LAMA/FOL2/ALWAYS $
$
DELETE /CASEDR,UPF,QPF,XYCDBDR,PUG $
CALL SUPER3  CASECC,        ,ULF,FOL2,PPF1,PSF1,     ,FOL1,UHF1,DLT,
$            CRX  ,CASEBK1,QRG
                 ,         ,   ,,,,
             PCDB,XYCDB,POSTCDB,/MUGNI,
             UPF,QPF,CASEDR,XYCDBDR,PUG,,,
             OUPF1,OPPF1,OQPF1,OFEF1,OFES1,OFEE1,,
             OUPF2,OPPF2,OQPF2,OFEF2,OFES2,OFEE2,,
             ,,,,,,/
$                             /CYCLIC/NLHEAT/AERO
             APP/APP1/RSONLY/FALSE /FALSE /FALSE/0/FS/
             S,PFILE/S,CARDNO/0/FALSE/RMSTRAIN/BETA/LMODES $
    IF ( MAXITER = -1) THEN $
      ADD MUGNI,/ZUZR13/(1.0,0.0) $
    ELSE IF ( KNT = -1 ) THEN $
      CONST1=CMPLX(BETA,0.0) $
      ADD MUGNI,/ZUZR13/CONST1 $
    ELSE $
       ADD ZUZR14,MUGNI/DIF/(-1.0,0.0) $
       NORM DIF/DIFN///S,N,XNORM $
       MESSAGE //' ITERATION NO.(-1=linear)= '/KNT/' XNORM= '/XNORM $
      norm ZUZR14/ugnin///s,n,ugnimax $
      norm mugni/mugnin///s,n,mugnimax $
      message //'ugnimax= '/ugnimax $
      message //'mugnimax= '/mugnimax $
      Z4=(UGNIMAX-MUGNIMAX)/MUGNIMAX $
      IF ( ABS( Z4 ) < ABSNORM ) KNT=MAXITER+1 $
        MESSAGE //'ABSOLUTE NORM ='/Z4 $
      CONST1=CMPLX(BETA,0.0) $
      CONST2=CMPLX(1.0-BETA,0.0) $
      ADD MUGNI,ZUZR14/ZUZR13/CONST1/CONST2 $
     ENDIF $
      DELETE /MUGNI,,,, $
      EQUIVX ZUZR13/MUGNI/ALWAYS $
      EQUIVX MUGNI/ZUZR14/ALWAYS $
   EQUIVX BGPDTS/ZUZR11/KNT $
   KNT=KNT+1 $
   dbview mestnl=estnl (where lgdisp=1) $
ENDDO $
NLOOP=0 $ SET QUALIFIER FOR PST AND DATA RECOVERY
    OUTPUT2 ....//-1/12/LABEL=PDALABEL $
         SDR2      CASEDR,CSTMS,,,EQEXINS,,,FOL2,BGPDTS,,,MUGNI,,/
                   ,,OUGV1PAT,,,/APP1 $
         OUTPUT2  OUGV1PAT//0/12 $
    OUTPUT2 ....//-9/12 $
IF ( DYNSEN='YES' ) THEN $
   EQUIVX     UPF/UPFDS/DDRMM $
   EQUIVX     QPF/QPFDS/DDRMM $
   PURGEX     /ULFDS,,,,/DDRMM $
   IF ( DDRMM>-1 ) THEN $
      DELETE         /FOL1,PPF1,PSF1,UHF1, $ AVOID OUTPUT TWICE
      CALL MODACC  CASES,FOL,UHF,PPF,PDF,PSF,PHDH,
                   USETD,,,,,/
                   FOL1,PPF1,ULFDS,PSF1,UHF1/
                   APP/APP/NOUE/-1/SOLTYP/FALSE/'YES   ' $
      CALL SUPER3  CASECC,,ULFDS,FOL1,PPF1,PSF1,,
                   FOL1,UHF1,DLT,,,,,,,PCDB,XYCDB,POSTCDB,/MUGNI,
                   UPFDS,QPFDS,CASEDR,XYCDBDR,PUG,,,
                   ,,,,,,,,,,,,,,,,,,,,,/
                   APP/APP/RSONLY/FALSE /FALSE /FALSE/2/FS/
                   S,PFILE/S,CARDNO/0/FALSE/RMSTRAIN/BETA/LMODES $
   ENDIF $ DDRMM>-1
   PUTSYS(1,109) $  FORCE EXECUTION ON RESTART
   CALL DYNSEN  UPFDS,QPFDS,ECTS,EPTS,EST,ETT,DIT,MPTS,GPECT,CASES,
                CSTMS,EQEXINS,FOL1,,BGPDTS,PPF1,VELEM,EDOMX,GEOM2S,SILS,
                KDICT,KELM,USETD,GMD,GOD,PHDH,KHH,BHH,MHH,,
```

```
                USET,GOAT,GM,KFS,KSS,,,DEQATN,DEQIND,GEOM3S,SLT,
                XINIT,EQIDNO,PLIST2,PLIST3,CONSBL,DPLDXI,DXDXIT,
                DTOS2,DTOS3,DTOS4,DSCREN,TABDEQ,DVP,DVTH,DTB,
                DEQCON,DEQPOS,DESGRD,DESGID,COORDN,DCLDXT,CON//
                SEID/G/NOUE/APP/SOLTYP/0./0./0/WTMASS/
                COUPMASS/K6ROT $
ENDIF $ DYNSEN='YES'
$
IF ( DBDICT>=2 ) DBDIR  //DBDRPRJ/DBDRVER/DBDROPT $
END $  SEMELRR
```

Appendix B Additional User Defined Parameters

PARAMETER NAME	DEFAULT	DESCRIPTION
ABSNORM	0.05	Absolute norm
BETA	0.5	Specifies control factor for converge enhancement. Ranges from 0.0 to 1.0
KNT	−1	Sets iteration counter
LGDISP	−1	Selects large displacement effects
LMODES	1	Requests the number of modes (uses with EIGRL card selection)
MAXITER	5	Requests the maximum number of iterations
MAXNORM	1.0E-3	Defines converged rms displacement norm
RMSTRAIN	−1	Requests the rms strains
XNORM	1.0E-3	Sets norm of rms displacements

Appendix C SUBDMAP SEDRCVR

```
SUBDMAP SEDRCVR  UGVS,QGS,BGPDTS,EQEXINS,CSTMS,CASEDR,MPTS,DIT,
                 ETT,OLB1,PJ1,EST,XYCDBDR,GEOM2S,GEOM3S,POSTCDB,
                 ECTS,GPLS,EPTS,SILS,INDTA,KELM,KDICT,GPECT,VELEM,
                 FORCE,XYCDB,PG,PCDBDR,USET,SLT,UNVF,OLBM,PGD,DLT,
                 FRL,SPSEL,DYNAMICS,CRX,QGE,OEFNLXX,OESNLXX/
                 MUGNI,PUGV,
                 QUGV1,QPG1,QQG1,QEF1X,QES1X,QSTR1,QGS1,
                 QUGV2,QPG2,QQG2,QEF2, QES2, QSTR2,QGS2,
                 QES1M,QES1G,QSTR1M,QSTR1G,EGPSTR,EGPSF,QNRGY1,QGPFB1/
                 GRDPNT/APP/APP1/NOCOMPS/CURVPLOT/PFILE/NUMOUT1/
                 NUMOUT2/BIGER1/BIGER2/NUMOUT/BIGER/SRTOPT/LSTRN/
                 SRTELTYP/CURV/OUTOPT/OG/NINTPTS/S1M/S1G/S1AM/
                 S1AG/DOPT/TINY/NOELOP/NOELOP/TABS/SEID/S1/CARDNO/
                 PDRMSG/SCRSPEC/RSPECTRA/RSPRINT/TABID/INREL/GPFDR/
                 NLHEAT/AERO/ICYCLIC/FS/GEOMU/LOADU/POSTU/
                 DBCDIAG/DBCPROG/POST/CP/DBCOVWRT/
                 OUNIT2/OTAPE2/OQG/OUG/OEF/OES/OEE/OCMP/OGPS/
                 OESE/OUMU/OGPF/OUGCORD/DESITER/RMSTRAIN/BETA/
                 LMODES $
$
TYPE DB BGPDP,HOEF1,OEF1,OEF1X,OEF2,OEF2Y,OES1,
        OES1G,OES1M,OES1X,OES1X1,OES2,OES2Y,OGPFB1,
        OGS1,OGS2,ONRGY1,OPG1,OPG2,OQG1,OQG2,
        OQG2Y,OSTR1,OSTR1G,OSTR1M,OSTR2,OSTR2Y,OUGV1,
        OUGV2,OUGV2Y,PG1,QEF1,SIP $ SCRATCH
TYPE DB GEOM1S,PTELEM,KJJ $ FOR POST=0 - DBC
TYPE DB PJC $ CYCLIC STATICS - FOR GPFDR
TYPE PARM,,I,N,CP,ICYCLIC,GEOMU,LOADU,POSTU $
TYPE PARM,,I,Y,DBCDIAG,RMSTRAIN $
TYPE PARM,,CHAR8,N,DBCPROG $
TYPE PARM,,CHAR8,Y,DBCOVWRT,MPCF,ACOUT='PEAK' $
TYPE PARM,,RS,Y,PREFDB=1. $
TYPE PARM,NDDL,I,N,ACOUSTIC $ ACOUSTIC ELEMENT FLAG - SET IN SEPREP2
TYPE PARM,NDDL,I,N,DBCPATH $ DUMMY PARAMETER TO PASS QUALIFIERS
TYPE DB,MELM,MDICT,LAMA $ FOR POST=-2
$  LOCAL PARAMETERS
TYPE PARM,,I,N,PFILE,SEID,CARDNO,RECORD,NM,NOXOUT=-1,DESITER $
TYPE PARM,,CHAR8,N,APP,APP1,APP2 $
TYPE PARM,,LOGICAL,N,SORT2,STATICS,GPFDR,NLHEAT,STATNH,AERO,FS $
$  USER PARAMETERS
TYPE PARM,,I,Y,POST,GRDPNT,NOELOP,NOELOP,CURVPLOT,S1AM,S1AG,LSTRN $
TYPE PARM,,I,Y,CURV,NUMOUT1,NUMOUT2,NUMOUT,SRTOPT,SRTELTYP $
TYPE PARM,,I,Y,NOMSGSTR,S1,S1M,S1G,OUTOPT,OG,NINTPTS,DOPT,PDRMSG $
TYPE PARM,,I,Y,RSPRINT,TABID $
TYPE PARM,,RS,Y,BIGER1,BIGER2,BIGER,TINY,TABS $
$  USER PARAMETERS APPLIED TO ALL SE AND RESOLVED IN SUPER1
TYPE PARM,,I,N,INREL $
$  USER PARAMETERS RESOLVED IN SUPER3
TYPE PARM,,I,N,SCRSPEC,RSPECTRA,NOCOMPS $
TYPE PARM,,CS,N,ALPHA=(1.0,0.0) $
TYPE PARM,,CS,N,ALPHA1=(1.0,0.0) $
TYPE PARM,,RS,N,RMSDIS1,FREQ1 $
TYPE PARM,,RS,N,Z1,Z2,Z5 $
TYPE PARM,,RS,Y,BETA $
TYPE PARM,,I,Y,CON1,LMODES,I $
$+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
$  OUTPUT2 CONTROLS
$
$ THE OUTPUT2 DMAP INSTRUCTIONS IN THIS SUBDMAP HAVE BEEN SUPPLIED
$ AS A COURTESY TO PDA/PATRAN AND SDRC/I-DEAS USERS AND QUESTIONS
$ AS TO HOW IT INTERFACES WITH THE PATRAN OR I-DEAS PROGRAM SHOULD
$ BE DIRECTED TO:
$
$    PATRAN USERS CONTACT:             I-DEAS USERS CONTACT:
$    ---------------------             ---------------------
$    PDA ENGINEERING                   SDRC
$    2975 REDHILL AVE.                 2000 EASTMAN DR.
$    COSTA MESA, CA  92626             MILFORD, OH  45150
$
$   PARAM,POST,-1, OUTPUTS THE APPROPIATE FILES FOR
$                  THE PDA/PATRAN NASPAT PROGRAM VERSION 2.0.
$
$   PARAM,POST,-2, OUTPUTS THE APPROPIATE FILES FOR
$                  THE SDRC/I-DEAS DATA LOADER PROGRAM VERSION 3.0.
$
TYPE PARM,,CHAR8,Y,OQG,OUG,OEF,OES,OEE,OCMP,OGPS,OESE $
TYPE PARM,,CHAR8,Y,OUMU,OGPF,OUGCORD $
TYPE PARM,,I,Y,OUNIT2,OMAXR $
TYPE PARM,,I,N,OTAPE2 $
FILE     PSDF=SAVE,OVRWRT $
$+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
STATICS=(APP='STATICS' OR APP='NLST' OR
        (APP='CYC' AND APP1='STATICS')) $
$
PARAML  SILS//'TRAILER'/1/S,N,NSILS $
PARAML  SILS//'TRAILER'/2/S,N,LUSETS $
IF ( NOT(STATICS OR NLHEAT) AND (NSILS*6)<>LUSETS ) THEN $
   PLTTRAN   BGPDTS,SILS/BGPDP,SIP/LUSETS/S,N,LUSEP $
ELSE $
   EQUIVX    BGPDTS/BGPDP/ALWAYS $
   EQUIVX    SILS/SIP/ALWAYS $
   LUSEP=LUSETS $
ENDIF $
$
IF ( APP='STATICS ' AND NOT(NLHEAT) OR
     (APP='REIG    ' AND APP1<>'BKL1    ')) THEN $
   VECPLOT  QGS,BGPDP,EQEXINS,CSTMS,CASEDR,/QGSUM/GRDPNT/0/1/
            'SPCFORCE' $
   VECPLOT  QGS,BGPDP,EQEXINS,CSTMS,CASEDR,/QGB//0/5/'MAXIMUM'/
            'SPCFORCE'/'S' $
   VECPLOT  UGVS,BGPDP,EQEXINS,CSTMS,CASEDR,/UGVB//0/5/'MAXIMUM'/
            'DISPLACE'/'MENTS' $
   IF ( APP='STATICS ' AND NOT(NLHEAT) ) VECPLOT,
           PJ1,BGPDP,EQEXINS,CSTMS,CASEDR,/PJB//0/5/'MAXIMUM'/
           'APPLIED'/'LOADS' $
ENDIF $
$
IF ( SCRSPEC>-1 ) RETURN $
$
EQUIVX UGVS/ZUZR19/ALWAYS $
EQUIVX UGVS/ZUZR20/ALWAYS $
MATMOD   UGVS,,,,,/ZUZR18,/1/1 $
DELETE /ZUZR18,ZUZR20,,, $
   Z5=0.0 $
   I=1 $
$   EXTRACT THE N-TH MODE (CONTROLLED BY VARIABLE I)
$   SO WE CAN HAVE THE SEPERATE RMS VALUES FOR EACH MODE
$   TOTAL RMS DISPLACEMENT IS IN Z5
DO WHILE (I<=LMODES) $
           MESSAGE //'THIS IS MODE # '/I $
   PARAML   UGVS//'TRAILER'/1/S,N,NOCOLS $ NOCOLS'S IN UGVS
   message //'LMODES= '/LMODES/'no. of columns= '/NOCOLS $
   MATGEN   ,/C/1/NOCOLS $
   MATMOD   C,,,,,/C1,/1/I $
   MATGEN   ,/A/7/1/NOCOLS $
   MATMOD A,,,,,/B,/12/S,N,NULLS/V,Y,NIM=1 $
   ADD B,C1/D/(1.0,0.0)/(-1.0,0.0) $
   MATMOD   UGVS,,,,,/UGVSXYI,/1/I $
   MERGE  UGVSXYI,,,,D,/UGVSX/1 $
   delete /ugvs,,,, $
   equivx ugvsx/ugvs/always $
$
SDR2      CASEDR,CSTMS,MPTS,DIT,EQEXINS,,ETT,OLB1,BGPDP,
          PJ1,QGS,UGVS,EST ,XYCDBDR/
          OPG1,OQG1,OUGV1,OES1,OEF1,PUGV/APP1/S,N,NOSORT2/
          NOCOMPS/////ACOUT/PREFDB $ SORT1 OLOADS, SPCFORCES,
$         NOCOMPS//ACOUT/PREFDB $ SORT1 OLOADS, SPCFORCES,
$         DISPLACEMENTS, ELEMENT STRESSES AND FORCES, PLOT VECTORS
SDR2      CASEDR,CSTMS,MPTS,DIT,EQEXINS,,ETT,OLB1,BGPDP,
          PJ1,QGS,UGVS,EST ,
          /,,,OSTR1,,/
          APP1/S,N,NOSTR2/3/////ACOUT/PREFDB $ SORT1 ELEMENT STRAINS
$         APP1/S,N,NOSTR2/3//ACOUT/PREFDB $ SORT1 ELEMENT STRAINS
IF ( APP='FREQRESP' AND NOT(AERO) AND ACOUSTIC>0 ) SDR2,
    CASEDR,CSTMS,MPTS,,EQEXINS,,,OLB1,BGPDP,,,UGVS,EST,/
    ,,OUG1F,,,/
    APP///ACOUSTIC////ACOUT/PREFDB $ SORT1 ACOUSTIC PRESSURE OUTPUT
$   APP///ACOUSTIC/ACOUT/PREFDB $ SORT1 ACOUSTIC PRESSURE OUTPUT
EQUIVX   OPG1/QPG1/ALWAYS $
EQUIVX   OQG1/QQG1/ALWAYS $
EQUIVX   OUGV1/QUGV1/ALWAYS $
EQUIVX   OSTR1/QSTR1/ALWAYS $
$
IF ( MPCF='YES' AND STATICS ) THEN $
   ADD5     PJ1,QGS,,,/PQ $
   MPYAD    KJJ,UGVS,PQ/QGM///-1 $
   SDR2     CASEDR,CSTMS,MPTS,DIT,EQEXINS,,ETT,OLB1,BGPDP,
            ,QGM,,EST,/
            ,OQGM,,,,/APP1/S,N,NP/NOCOMPS $
   MESSAGE  //'                                                '/
            ' M U L T I P O I N T   F O R C E S   O F   '/
            'C O N S T R A I N T' $
   OFP      OQGM// $
ENDIF $
$
$ OLD DMAP -- IF FIXEDB < 0 THEN STORE PUGV??
$   EQUIV PUGV WILL PULL PATH TO PUGVS WITH PATH SEGMOM
$
IF ( POST<0 AND OQG='YES' ) THEN $
$**   OUTPUT2  OQG1//OTAPE2/OUNIT2//OMAXR $
   OTAPE2=0 $
ENDIF $
$
IF ( POST=-2 AND STATICS AND NOT(AERO) AND
     GETSYS(NM,56)<>0 ) SDR2,
              CASEDR,CSTMS,MPTS,DIT,EQEXINS,,ETT,OLB1,BGPDP,
              PJ1,QGS,UGVS,EST ,XYCDBDR/
              ,,TOUGV1,,,/APP1/S,N,NOSORT2/NOCOMPS $
$
IF ( POST<0 AND OUG='YES' ) THEN $
   IF ( POST=-2 AND STATICS AND NOT(AERO) AND
        GETSYS(NM,56)<>0 ) THEN $
$**      OUTPUT2  TOUGV1//OTAPE2/OUNIT2//OMAXR $
   ELSE IF ( OUGCORD='BASIC' ) THEN $
      VECPLOT  UGVS,BGPDP,EQEXINS,CSTMS,CASEDR,/UGVSB//0/1 $
      IF ( POST=-1 ) THEN $
         SDR2     CASEDR,CSTMS,,,EQEXINS,,,OLB1,BGPDTS,,,UGVSB,,/
                  ,,OUGV1PAT,,,/APP1 $
$**         OUTPUT2  OUGV1PAT//OTAPE2/OUNIT2//OMAXR $
      ELSE IF ( POST=-2 ) THEN $
         IF ( APP1='REIG' ) THEN $
            SDR2     CASEDR,CSTMS,,,EQEXINS,,,OLB1,BGPDTS,,,UGVSB,,/
                     ,,BOPHIG,,,/APP1 $
$**            OUTPUT2  BOPHIG//OTAPE2/OUNIT2//OMAXR $
         ELSE $
            SDR2     CASEDR,CSTMS,,,EQEXINS,,,OLB1,BGPDTS,,,UGVSB,,/
                     ,,BOUGV1,,,/APP1 $
$**            OUTPUT2  BOUGV1//OTAPE2/OUNIT2//OMAXR $
         ENDIF $
      ENDIF $
   ELSE $
$**      OUTPUT2  OUGV1//OTAPE2/OUNIT2//OMAXR $
   ENDIF $
   OTAPE2=0 $
```

```
ENDIF $
$
IF ( POST<0 AND OES='YES' ) THEN $
$**   OUTPUT2  OES1//OTAPE2/OUNIT2//OMAXR $
   OTAPE2=0 $
ENDIF $
$
IF ( ((STATICS AND NOT(AERO)) OR NLHEAT) AND
     (GETSYS(NH,56)<>0) AND SEID=0 ) THEN $
   SDRHT     SILS,USET ,UGVS,OEF1,SLT,EST ,DIT,QGE,DLT,/HOEF1/
             TABS/0 $
   DELETE    /OEF1,..., $
   EQUIVX    HOEF1/OEF1/ALWAYS $
   EQUIVX    HOEF1/QEF1/ALWAYS $
ENDIF $
$
IF ( OEF='YES' ) THEN $
   IF ( POST=-2 AND STATICS AND NOT(AERO) AND
        GETSYS(NH,56)<>0 ) THEN $
$**        OUTPUT2  HOEF1//OTAPE2/OUNIT2//OMAXR $
      OTAPE2=0 $
   ELSE IF ( POST<0 ) THEN $
$**        OUTPUT2  OEF1//OTAPE2/OUNIT2//OMAXR $
      OTAPE2=0 $
   ENDIF $
ENDIF $
$
IF ( POST<0 AND OEE='YES' ) THEN $
$**   OUTPUT2  OSTR1//OTAPE2/OUNIT2//OMAXR $
   OTAPE2=0 $
ENDIF $
$
IF ( APP='NLST' AND SEID=0 ) THEN $
   MERGEOFP OEF1,OEFNLXX/OEF1X $
   MERGEOFP OES1,OESNLXX/OES1X $
ELSE $
   IF ( STATICS OR APP='REIG     ' ) THEN $
      SDRX      CASEDR,OEF1,OES1,GEOM2S,GEOM3S,EST,CSTMS,MPTS,DIT/
                OEF1X,OES1X/S,N,NOXOUT $
   ELSE IF ( APP1<>'MMREIG' ) THEN $
      SDRXD     CASEDR,OEF1,OES1,GEOM2S,GEOM3S,EST,CSTMS,
                MPTS,DIT,UGVS,DLT,OLB1/
                OEF1X,OES1X/S,N,NOXOUT/APP/COUPMASS $
   ENDIF $
   EQUIVX    OEF1/OEF1X/NOXOUT $
   EQUIVX    OES1/OES1X/NOXOUT $
ENDIF $ APP='NLST' AND SEID=0
$
EQUIVX    OEF1X/QEF1X/ALWAYS $
EQUIVX    OES1X/QES1X/ALWAYS $
$
STATNH=(STATICS AND NOT(NLHEAT)) $
IF ( APP1<>'MMREIG' AND (STATNH OR
     (APP='REIG' AND APP1<>'BKL1') OR APP='TRANRESP') ) THEN $
   PARAML   POSTCDB//'PRESENCE'////S,N,NOPOST $
   IF ( NOPOST > -1 ) THEN  $ $ GRID POINT STRESS FACTORS
      PLTSET    POSTCDB,EQEXINS,ECTS/PLTP,PLTPARP,CPSETP,ELSETP/
                S,N,NSILS $
      GPSTR1    POSTCDB,BGPDTS,ECTS,CSTMS,ELSETP,EPTS,EQEXINS/EGPSF  $
$                EGPSF - ELEMENT TO GRID POINT SURFACE FACTORS
   ENDIF $ GRID POINT STRESS FACTORS
   PARAML   EGPSF//'PRESENCE'////S,N,NOEGPSF $
   PARAML   OES1X//'PRESENCE'////S,N,NOOES1 $
   IF ( NOEGPSF>-1 AND NOOES1>-1 ) THEN $
$               SORT1 GRID POINT STRESSES
      GPSTR2    CASEDR,EGPSF,GPLS,OES1X/OGS1,EGPSTR///APP $
      EQUIVX    OGS1/QGS1/ALWAYS $
$
$       MESH ERROR ANALYSIS - LINEAR STATIC ANALYSIS ONLY
      PARAML   EGPSTR//'PRESENCE'////S,N,NOEGPSTR $
      IF ( NOEGPSTR>-1 AND STATICS AND NOT(APP='NLST') ) STDCON,
                   CASEDR,EGPSF,EQEXINS,OES1X,EGPSTR,ECTS/
                   OEDS1,OGDS1,ELDCT,GPDCT/
                   S,N,NOEDS1/S,N,NOGDS1/S,N,NOEDT1/S,N,NOGDT1/APP $
$
      IF ( POST=-1 AND OGPS='YES' ) THEN $
$**          OUTPUT2  OGS1//OTAPE2/OUNIT2//OMAXR $
         OTAPE2=0 $
      ENDIF $
$
   ENDIF $ NOEGPSF>-1 AND NOOES1>-1
ENDIF $
$
SORT2=NOT(ANDL(NOSORT2,NOSTR2)) $
$ IF FLUID/STRUCTURE MODEL AND FREQUENCY RESPONSE, THEN
$    DO SORT2 EVEN THOUGH DDRMM=-1,
$    BUT DO NOT PERFORM MATRIX METHOD DATA RECOVERY (DDRMM)
IF ( APP1='MMREIG  ' OR
     (CURVPLOT=-1 AND (SORT2 OR (FS AND APP='FREQRESP'))) ) THEN $ SORT2
   SDR3      OUGV1,OPG1,OQG1,OEF1X,OES1X,OSTR1/
             OUGV2,OPG2,OQG2,OEF2,OES2,OSTR2 $  SORT2 OUTPUT
   SDR3      OUG1F...../OUG2F..... $
   IF ( STATNH OR APP='REIG     ' OR
        (APP='TRANRESP' AND NOT(NLHEAT)) ) SDR3,
                     OGS1,OGDS1,OEDS1.../OGS2,OGDS2,OEDS2... $
   IF ( APP1='MMREIG  ' ) THEN $
      IF (SEID=0) THEN $
         DELETE    /OPG1,OPG2.../ $  FROM SDR2 ABOVE
         SDR2      CASEDR,...,EQEXINS...OLBM,,PGD,...XYCDBDR/
                   OPG1,..../APP $
         SDR3      OPG1,..../OPG2,..../ $
      ENDIF $
      DDRMM     CASEDR,UHVF,OLBM,OUGV2,OQG2,OES2,OEF2,XYCDBDR/
                OUGV2Y,OQG2Y,OES2Y,OEF2Y,/ $
      EQUIVX    OUGV2Y/OUGV2/ALWAYS $
      EQUIVX    OQG2Y/OQG2/ALWAYS $
      EQUIVX    OES2Y/OES2/ALWAYS $
      EQUIVX    OEF2Y/OEF2/ALWAYS $
      DDRMM     CASEDR,UHVF,OLBM,,,OSTR2,,XYCDBDR/,,OSTR2Y,,//3 $
      EQUIVX    OSTR2Y/OSTR2/ALWAYS $
   ENDIF $ APP1='MMREIG
$
   EQUIVX    OPG2/QPG2/ALWAYS $
   EQUIVX    OQG2/QQG2/ALWAYS $
   EQUIVX    OUGV2/QUGV2/ALWAYS $
   EQUIVX    OES2/QES2/ALWAYS $
   EQUIVX    OEF2/QEF2/ALWAYS $
   EQUIVX    OSTR2/QSTR2/ALWAYS $
   EQUIVX    OGS2/QGS2/ALWAYS $
$
   IF (RMSTRAIN=2) THEN $
   OFP       OUGV2,OPG2,OQG2,OEF2,OES2,OSTR2//S,N,CARDNO $
   OFP       OGDS2,OEDS2,OUG2F//S,N,CARDNO $
   ENDIF $
$
   IF ( STATNH OR APP='REIG     ' OR
        (APP='TRANRESP' AND NOT(NLHEAT)) ) OFP   OGS2//S,N,CARDNO $
   XYTRAN    XYCDBDR,OPG2,OQG2,OUGV2,OES2,OEF2/XYPLTT/APP/'PSET'/
             S,N,PFILE/S,N,CARDNO/S,N,NOXYP $
   IF ( NOXYP >=0 ) XYPLOT    XYPLTT// $
$
   IF ( RSPECTRA>=0 ) THEN $
$   SKIP IF NONLINEAR ANALYSIS
      RECORD=0 $  INITIALIZE
      DO WHILE ( RECORD<>-1 ) $
         RSPEC PRL,OUGV2,SPSEL/OXRESP/S,N,RECORD $
         IF ( RECORD>=0 ) THEN $
            IF ( RSPRINT>=0 ) OFP   OXRESP//S,N,CARDNO $
               XYTRAN    XYCDBDR,OXRESP,.../XYPLTSS/'RSPEC'/'PSET'/
                         S,N,PFILE/S,N,CARDNO/S,N,NOXYPLT/TABID $
               IF ( NOXYPLT>=0 ) XYPLOT  XYPLTSS// $
            ENDIF $
         ENDDO $ RECORD<>-1
$
   ELSE IF ( APP = 'FREQRESP' ) THEN $ RSPECTRA>=0
      DPD       DYNAMICS,GPLS,SILS,USET,,/
                XGPL,XSIL,XUSET,,MPSDL,...,XEQDYN/
                -1/DUM2/0/0/S,N,NOPSDL/0/0/    0  /  1   /123/DUM10 $
$                                              DYNSTAT/NEWDYN
      IF ( NOPSDL > -1 ) THEN
$          DELETE /PSDF,AUTO,.. $
      IF ( RMSTRAIN = 1) THEN
$   matprn MPSDL,OEF2 // $
$   matprn XYCDBDR,MPSDL,OUGV2,OEF2,CASEDR // $
         RANDOM    XYCDBDR,DIT,MPSDL,OUGV2,OPG2,OQG2,OSTR2,OEF2,CASEDR/
                   PSDF,AUTO/S,N,NORAND $
   PARAML   OSTR2//'PRESENCE'////S,N,NOOSTR2 $
   MESSAGE //'OSTR2(09-14-92)= '/NOOSTR2 $
$   OUTPUT2 ....//-1/12/LABEL=PDALABEL $
$        OUTPUT2  OSTR1//0/12 $
$   OUTPUT2 ....//-9/12 $
      ELSE $
         RANDOM    XYCDBDR,DIT,MPSDL,OUGV2,OPG2,OQG2,OES2,OEF2,CASEDR/
                   PSDF,AUTO/S,N,NORAND $
      ENDIF $
         IF ( NORAND > -1 ) THEN $
           XYTRAN    XYCDBDR,PSDF,AUTO,../
                     XYPLTRS/
                     'RAND'/'PSET'/S,N,PFILE/S,N,CARDNO/S,N,NOXYPLT $
           IF ( NOXYPLT > -1 ) XYPLOT   XYPLTRS// $
         ENDIF $
      ENDIF $
   ENDIF $ ELSE IF APP=FREQRESP
$
   IF ( POST=0 ) THEN $
      DBC       OPG2,OUGV2,OEF2,OES2,OQG2,GPLS,EGPSTR,EGPSF,GPDCT,
                ELDCT,..........//
                'OPG'/'OUG'/'OEF'/'OES'/'OQG'/'GPL'/'GPS'/'SVF'/'GPDCT'/
                'ELDCT'///////////
                -1/DBCPATH/S,N,CP/APP1/ICYCLIC/GEOMU/LOADU/POSTU/
                DBCDIAG/DBCPROG/DBCOVWRT/DESITER $
      DBC       OSTR2,..................//
                'OES'////////////////////
                -1/DBCPATH/S,N,CP/APP1/ICYCLIC/GEOMU/LOADU/POSTU/
                DBCDIAG/DBCPROG/DBCOVWRT/DESITER $
      DBC       OUG2F,..................//
                'OUG'////////////////////
                -1/DBCPATH/S,N,CP/APP1/ICYCLIC/GEOMU/LOADU/POSTU/
                DBCDIAG/DBCPROG/DBCOVWRT/DESITER $
   ENDIF $ POST=0
$
$   SCALED SPECTRA RESPONSE NOT INCLUDED HERE
$
ELSE $ APP1='MMREIG  ' OR  ((CURVPLOT=-1 OR FS) AND SORT2)
   OFP       OUGV1,OPG1,OQG1,OEF1X,OSTR1//S,N,CARDNO $
   OFP       OGDS1,OEDS1,OUG1F//S,N,CARDNO $
   IF ( NOT(STATICS OR APP='REIG     ') ) OFP   OES1X//S,N,CARDNO $
   IF ( STATICS OR APP='REIG     ' OR
        APP='TRANRESP' ) OFP   OGS1//S,N,CARDNO $
   IF ( STATICS OR APP='REIG     ' ) THEN $
   IF ( NOCOMPS >= 0 ) THEN $ NOCOMPS >= 0 COMPOSITE PLY STRESS
      SDR2      CASEDR,CSTMS,MPTS,DIT,EQEXINS,,ETT,OLB1,BGPDP,
                PJ1,QGS,UGVS,EST,XYCDBDR/
                ,,,OES1A,,/'STATICS '/S,N,NOS/2 $
      SDRCOMP   CASEDR,MPTS,EPTS,ETT,EST,OES1A,OEF1,DIT/
                ES1C,EFIT,/LSTRN $
      STRSORT   ES1C,/OES1C/NUMOUT1/BIGER1 $
      STRSORT   EFIT,/OEFIT/NUMOUT2/BIGER2 $
      OFP       OES1C,OEFIT,,//S,N,CARDNO $
      IF ( POST=-2 AND OCMP='YES') THEN $
         MATMOD    OES1C,..../OSTR1C,/13 $
         OUTPUT2   OES1C,OEFIT//OTAPE2/OUNIT2//OMAXR $
         OTAPE2=0 $
      ENDIF $
```

```
$
   ENDIF $ NOCOMPS >= 0 COMPOSITE PLY STRESS
$
   EQUIVX    OES1X/OES1X1/S1 $
   IF ( S1 >= 0 ) STRSORT  OES1X,INDTA/OES1X1/NUMOUT/BIGER/
                           SRTOPT/SRTELTYP $  ELEMENT STRESS SORTING
   OFP       OES1X1//S,N,CARDNO $  $    PRINT ELEMENT STRESSES
$
   PARAML   FORCE//'PRESENCE'////S,N,NOFORCE $
   IF ( NOMSGSTR >= 0  AND NOFORCE >= 0 ) MSGSTRES  FORCE,OES1X/
                                          /S,N,PFILE/NOMSGSTR $
$
   IF ( CURV >= 0 ) THEN $  STRESS/STRAIN TRANSFORMATION TO GRID POINTS
$                           OR MATL COORD SYSTEM
$     SEE RF24D40 IN UM 3.5 FOR PARAMETER EXPLANATION
      CURV      OES1X,MPTS,CSTMS,EST ,SILS,GPLS/OES1M,OES1G/OUTOPT/
                OG/NINTPTS $
      EQUIVX    OES1M/QES1M/ALWAYS $
      EQUIVX    OES1G/QES1G/ALWAYS $
      IF ( S1M >= 0 ) THEN  $
         STRSORT  OES1M,INDTA/OES1M1/NUMOUT/BIGER/SRTOPT/SRTELTYP $
         OFP      OES1M1//S,N,CARDNO $  PRINT STRESSES IN MATL COORD SYS
      ENDIF $
      IF ( S1G >= 0 ) THEN $
         STRSORT  OES1G,INDTA/OES1G1/NUMOUT/BIGER/SRTOPT/SRTELTYP $
         OFP      OES1G1//S,N,CARDNO $  PRINT STRESSES AT GRID POINTS
      ENDIF $
      DIAGON(23) $
      CURV      OSTR1,MPTS,CSTMS,EST ,SILS,GPLS/OSTR1M,OSTR1G/OUTOPT/
                OG/NINTPTS  $  STRAINS
      DIAGOFF(23) $
      EQUIVX    OSTR1M/QSTR1M/ALWAYS $
      EQUIVX    OSTR1G/QSTR1G/ALWAYS $
      IF ( S1AM >= 0 ) OFP  OSTR1M//S,N,CARDNO $ PRINT STRAINS IN
$                                                MATL COORD SYS
      IF ( S1AG >= 0 ) OFP  OSTR1G//S,N,CARDNO $ PRINT STRAINS AT
$                                                GRID POINTS
   ENDIF $  STRESS/STRAIN TRANSFORMATION TO GRID POINTS OR MATL COORD SY
$
   PARAML   XYCDB//'PRESENCE'////S,N,NOXYCDB $
   IF ( NOXYCDB >= 0 ) THEN $
      CURVPLOT EQEXINS,BGPDTS,OLB1,XYCDBDR,OPG1,OQG1,OUGV1,OES1G,/
               OPG2X,OQG2X,OUG2X,OES2X,/DOPT $
      XYTRAN   XYCDBDR,OPG2X,OQG2X,OUG2X,OES2X,/XYPLTS/'SET1'/'PSET'/
               S,N,PFILE/S,N,CARDNO/S,N,NOXYP $
      IF ( NOXYP >= 0 ) XYPLOT   XYPLTS// $
   ENDIF $ CURVPLOT
$
   IF ( GPFDR ) THEN $ GRID POINT FORCE
      IF ( APP='CYC' AND APP1='STATICS' ) THEN $
         EQUIVX   PJC/PG1/ALWAYS $
      ELSE $
         EQUIVX   PJ1/PG1/ALWAYS $
      ENDIF $
      APP2=APP1 $
      IF ( APP='NLST' ) APP2='STATICS' $
      GPFDR     CASEDR,UGVS,KELM,KDICT,ECTS,EQEXINS,GPECT,PG1,QGS,
                BGPDTS,SILS,CSTMS,VELEM,PTELEM/
                ONRGY1,OGPFB1/APP2/TINY $
      EQUIVX    ONRGY1/QNRGY1/ALWAYS $
      EQUIVX    OGPFB1/QGPFB1/ALWAYS $
      OFP       ONRGY1,OGPFB1//S,N,CARDNO $
$
      IF ( POST<0 ) THEN $
         IF ( POST=-1 AND OGPF='YES' ) THEN $
            OUTPUT2  OGPFB1//OTAPE2/OUNIT2//OMAXR $
            OTAPE2=0 $
         ENDIF $
         IF ( OESE='YES' ) THEN $
            OUTPUT2  ONRGY1//OTAPE2/OUNIT2//OMAXR $
            OTAPE2=0 $
         ENDIF $
         IF ( POST=-2 AND OUMU='YES' AND APP='REIG' ) THEN $
            GPFDR     CASEDR,UGVS,MELM,MDICT,ECTS,EQEXINS,GPECT,PG1,QGS,
                      BGPDTS,SILS,CSTMS,VELEM,/
                      ONRGY2,OGPFB2/APP1/TINY $
            DBVIEW    XLAMA=LAMA (WHERE WILDCARD=TRUE) $
            OUTPUT2   XLAMA,ONRGY2//OTAPE2/OUNIT2//OMAXR $
            OTAPE2=0 $
         ENDIF $
      ENDIF $
      IF ( NOELOF >= 0 OR NOELOP >= 0 ) THEN $
         ELFDR     OGPFB1,GPECT ,CSTMS,SILS,GPLE,BGPDTS/OELOF1,OELOP1/
                   NOELOF/NOELOP $
         OFP       OELOF1,OELOP1//S,N,CARDNO $
      ENDIF $ ELEMENT ALIGNED GRID POINT FORCE
   ENDIF $ GRID POINT FORCE
   ENDIF $ STATICS OR APP='REIG    '
$
IF ( POST=0 ) THEN $
   DBC    OPG1,OUGV1,OEF1X,OES1X,OQG1,GPLS,EGPSTR,EGPSF,GPDCT,ELDCT,
          ONRGY1,OGPFB1,.......//
          'OPG'/'OUG'/'OEF'/'OES'/'OQG'/'GPL'/'GPS'/'SVF'/
          'GPDCT'/'ELDCT'/'OESE'/'OGPF'/////////
          -1/DBCPATH/S,N,CP/APP1/ICYCLIC/GEOMU/LOADU/POSTU/
          DBCDIAG/DBCPROG/DBCOVWRT/DESITER $
   DBC    OSTR1,..................//
          'OES'////////////////////
          -1/DBCPATH/S,N,CP/APP1/ICYCLIC/GEOMU/LOADU/POSTU/
          DBCDIAG/DBCPROG/DBCOVWRT/DESITER $
   DBC    OES1C,..................//
          'OESC'///////////////////
          -1/DBCPATH/S,N,CP/APP1/ICYCLIC/GEOMU/LOADU/POSTU/
          DBCDIAG/DBCPROG/DBCOVWRT/DESITER $
   DBC    OUG1F,..................//
          'OUG'////////////////////
          -1/DBCPATH/S,N,CP/APP1/ICYCLIC/GEOMU/LOADU/POSTU/
          DBCDIAG/DBCPROG/DBCOVWRT/DESITER $
ENDIF $
$
ENDIF $ APP1='MMREIG  ' OR  (CURVPLOT=-1 AND SORT2)
$
   paraml psdf//'dti'/1/8/s,n,rmsdis1 $
   Z5=Z5+RMSDIS1 $
   message //'rmsdis1= '/rmsdis1/'Z5= '/Z5 $
   paraml psdf//'dti'/1/5//s,n,nodeno $
   message //'node5= '/nodeno $
   NODENO=NODENO/10 $
   CON1=NODENO*6 - 3 $
   norm UGVSXYI/UGVSNORM///s,n,ugvsmax $
   paraml ugvsnorm//'dmi'/1/CON1/s,n,nodedis $
   message //'nodeno con1 nodedis='/nodeno/con1/nodedis $
   IF ( NODEDIS=0.000 ) THEN $
      MESSAGE  //' FATAL MESSAGE FROM THE MODIFIED DMAP'/
         ' THE GRID POINT '/NODENO/' HAS ZERO RMS DIS..'/
         ' PLEASE CHOOSE ANOTHER POINT IN THE "XYPLOT"'/
         ' OR "XYPRINT".' $
      EXIT $
   ENDIF $
$  rmsdis1=rmsdis1/nodedis $
   rmsdis1=rmsdis1/abs(nodedis) $
   paraml psdf//'dti'/1/9/s,n,freq1 $
     message //'frequency= '/freq1 $
        ALPHA1=CMPLX(-FREQ1,0.0) $
     message //'rmsdis1= '/rmsdis1 $
        ALPHA=CMPLX(RMSDIS1,0.0) $
   DELETE /F.... $
   ADD UGVSNORM,ZUZR18/F/ALPHA $
   EQUIVX F/ZUZR18/ALWAYS $
   NORM UGVSX/UGVSXNORM///s,n,ugvsxmax $
   DELETE /Z.... $
   ADD UGVSXNORM,ZUZR20/Z/ALPHA $
   DELETE /ZUZR20.... $
   EQUIVX Z/ZUZR20/ALWAYS $
   I=I+1 $
   EQUIVX ZUZR19/UGVS/ALWAYS $
ENDDO $ I<=LMODES $
$     RMSDIS1=Z5 $
   MESSAGE //'THE RMS DIS. AT POINT '/NODENO/' IS '/Z5/
             ' WITH TOTAL OF '/LMODES/' MODES' $
   DELETE /MUGNI.... $
   equivx zuzr18/mugni/always $
$
$    This is for separate modes
$
$  equivx zuzr20/mugni/always $
$
$ FIND LARGEST POSITIVE AND SMALLEST (NEGATIVE) TERMS IN MATRICES
$
$ INPUT MATRIX IS ZUZR03
$
   EQUIVX MUGNI/ZUZR03/ALWAYS $
   DIAGONAL ZUZR03/ABS/'WHOLE'/1. $
   ADD ABS,ZUZR03/POSITIVE/(.5,0.)/(.5,0.) $ REMOVE NEGATIVES
   MATMOD POSITIVE,..../MAX,/7 $ MAXIMUM VALUES
   ADD ABS,ZUZR03/NEGATIVE/(.5,0.)/(-.5,0.) $ REMOVE POSITIVES
   MATMOD NEGATIVE,..../MIN,/7 $ MINIMUM
   ADD MIN,/MINN/(-1.,0.) $
   norm MAX/outmax///s,n,localmax $
   norm MINN/outmin///s,n,localmin $
   message //'localmax= '/localmax/' localmin= '/localmin $
   IF ( LOCALMIN > LOCALMAX) THEN $
        ADD ZUZR03,/ZUZR04/(-1.0,0.0) $
   ELSE $
        ADD ZUZR03,/ZUZR04/(+1.0,0.0) $
   ENDIF $
$
  EQUIVX ZUZR04/MUGNI/ALWAYS $
  DELETE /ZUZR04,... $
  norm ZUZR18/DUMMY///s,n,maxdis $
  MESSAGE //'THE MAX RMS DIS. IS '/MAXDIS $
$
PARAML   PCDBDR//'PRESENCE'////S,N,JPLOT $  IS THERE AN OUTPUT(PLOT)
$                                           FOR THIS SUPERELEMENT ?
IF ( JPLOT >=0 ) THEN $  PHASE III DEFORMED AND CONTOUR PLOTTING
   PLTSET   PCDBDR,EQEXINS,ECTS/PLTX,PLTPARX,GPSETSX,ELSETSX/
            S,N,NSILS/S,N,JPLOT $
   PRTMSG   PLTX//PDRMSG $
   IF ( JPLOT >=0 ) THEN $ CREATE PLOT FILE
      PLOT     PLTPARX,GPSETSX,ELSETSX,CASEDR,BGPDTS,EQEXINS,SIP ,
               PUGV ,PUGV ,GPECT,OES1X/PLOTX2/NSILS/LUSEP/JPLOT/-1/
               S,N,PFILE $
      PRTMSG   PLOTX2//PDRMSG $
   ENDIF $ CREATE PLOT FILE
ENDIF $  PHASE III DEFORMED AND CONTOUR PLOTTING
RETURN $
END $ SEDRCVR
```

Appendix D SUBDMAP SUPER3

```
SUBDMAP SUPER3  CASERS,CASEUP,UL,OL2,PP1,PS1,PRL,OL1,UM,DLT,
                CRX,CASEEK1,QRG,PJR,OEFNLXX,OESNLXX,
                PCDB,XYCDB,POSTCDB,FORCE/MUGNI,
                UG,QG,CASEDR,XYCDBDR,PUG,BGPSF,OLBRS,
                OUGV1,OPG1,OQG1,OEF1X,OES1X,OSTR1,OGS1,
                OUGV2,OPG2,OQG2,OEF2, OES2, OSTR2,OGS2,
                OES1M,OES1G,OSTR1M,OSTR1G,EGPSTR,ONRGY1,OGPFB1/
                APP/APP1/RSONLY/CYCLIC/NLHEAT/AERO/DROPT/FS/
                PFILE/CARDNO/DESITER/NONLNR/RMSTRAIN/BETA/LMODES $
$
TYPE DB EPT,MPT,GEOM1,GEOM2,GEOM3,GEOM4,EMAP,MAPS,EQEXINS,
        PVTS,CASES,SLT,ETT,GOAT,GOAQ,LOO,KOO,LAO,POS,UOX,GPLS,USET,
        SILS,PJ,EDT,YS,GM,PSS,KFS,KSS,QR,CMPHO,CMLAMA,CMPHA,MAR,MEA,
        DYNAMICS,BGPDTS,CSTMS,MPTS,DIT,EST,GEOM2S,GEOM3S,ECTS,
        EPTS,INDTA,KELM,KDICT,GPECT,VELEM,FORE,SILX,EQEXINX,ECTX,
        BGPDTX,QGE,GEOM4S,PG,ESTL,SPSEL,USETNL $
TYPE DB CASEBK,CASEX,ESTN,GEOM3BK,GEOM3X,OLB2,PJ1,
        ULS,ULS1 $ SCRATCH
$ QUALIFERS
TYPE PARM,,RS,Y,RMSDIS1,BETA $
TYPE PARM,NDDL,I,Y,HIGHQUAL,LMODES $
TYPE PARM,NDDL,I,N,SEID,MTEMP,LOAD,TEMPLD,DEFORM,MPC,SPC $
TYPE PARM,NDDL,I,N,PEID,METH,DYRD,MFLUID,NL99,NLOOP $
TYPE PARM,NDDL,CHAR8,N,K2GG,M2GG,B2GG,P2G,APRCH $
TYPE PARM,NDDL,LOGICAL,N,FSCOUP $
$  LOCAL PARAMETERS
TYPE PARM,,CHAR8,N,APP,APP1,SUBDMAP='SUPER3',CNTL $
TYPE PARM,,LOGICAL,N,RSONLY,CYCLIC,GPFDR,NLHEAT,AERO,FS,NONLNR $
TYPE PARM,,I,N,NOSE,ENDDR,NOUPL,ENDPLOT=0,PFILE,CARDNO,NOQG,TSET $
TYPE PARM,,I,N,NOUSET,NOASET,NOBSET,NOCSET,NOGSET,NOLSET,NOOSET,NOQSET $
TYPE PARM,,I,N,NORSET,NOSSET,NOTSET,NOVSET,NOA,NOSET,NORC,NOMSET $
TYPE PARM,,I,N,RSPECTRX,SCRSPECX,NOCOMPX=-1,DESITER,EXTRCV1 $
$  USER PARAMETERS
TYPE PARM,NDDL,I,Y,PLTMSG,PDRMSG,GRDPNT,NOELOF,NOELOP,S1AG $
TYPE PARM,NDDL,I,Y,CURVPLOT,CURV,NOCOMPS,NUMOUT1,NUMOUT2,NUMOUT,LSTRN $
TYPE PARM,NDDL,I,Y,SRTOPT,SRTELTYP,NOMSGSTR,S1,S1M,S1G,OUTOPT,OG,S1AM $
TYPE PARM,NDDL,I,Y,NINTPTS,DOPT,IRES,RSPECTRA,RSPRINT,TABID $
TYPE PARM,NDDL,RS,Y,TABS,BIGER1,BIGER2,BIGER,TINY $
TYPE PARM,NDDL,I,Y,SESEF,SCRSPEC,EXTRCV $
$  USER PARAMETERS APPLIED TO ALL SE
$  AND SAVED ON DATA BASE IN PHASE0
TYPE PARM,NDDL,CHAR8,N,ALTRED,HEATSTAT $
TYPE PARM,NDDL,I,N,FIXEDB,INREL $
$  SAVED PARAMETERS
TYPE PARM,NDDL,LOGICAL,N,SKIPSE $
TYPE PARM,NDDL,I,N,NOUP $ FOR POSTREIG
$  DBC AND POST RELATED PARAMETERS
TYPE PARM,,I,N,ICYCLIC $
TYPE PARM,NDDL,I,N,CP,GEOMU,LOADU,POSTU,DBCPATH $ SCRATCH
TYPE PARM,NDDL,I,Y,DBCDIAG,POST $
TYPE PARM,NDDL,CHAR8,Y,DBCCONV,DBCOVWRT $
TYPE PARM,,CHAR8,N,DBCCONVX $
$
$ SEMELRR FLAGS
$
TYPE PARM,,I,Y,RMSTRAIN $
$+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
$   OUTPUT2 CONTROLS
$
$ THE OUTPUT2 DMAP INSTRUCTIONS IN THIS ALTER HAVE BEEN ENTERED INTO
$ THE MSC/NASTRAN RF ALTER LIBRARY AS A COURTESY TO PDA/PATRAN AND
$ SDRC/I-DEAS USERS AND QUESTIONS AS TO HOW IT INTERFACES WITH THE
$ PATRAN OR I-DEAS PROGRAM SHOULD BE DIRECTED TO:
$
$    PATRAN USERS CONTACT:             I-DEAS USERS CONTACT:
$    --------------------              --------------------
$    PDA ENGINEERING                   SDRC
$    2975 REDHILL AVE.                 2000 EASTMAN DR.
$    COSTA MESA, CA  92626             MILFORD, OH  45150
$
$   PARAM,POST,-1, OUTPUTS THE APPROPIATE FILES FOR
$                  THE PDA/PATRAN NASPAT PROGRAM VERSION 2.0.
$
$   PARAM,POST,-2, OUTPUTS THE APPROPIATE FILES FOR
$                  THE SDRC/I-DEAS DATA LOADER PROGRAM VERSION 3.0.
$
TYPE PARM,,CHAR8,Y,OQG='YES',OUG='YES',OEF='YES',OES='YES',OEE='YES' $
TYPE PARM,,CHAR8,Y,OCMP='YES',OGPS='YES',OESE='YES',OUMU='YES' $
TYPE PARM,,CHAR8,Y,OGPF='YES',OUGCORD=' ',OGEOM=' ' $
TYPE PARM,,I,Y,OUNIT1=11,OUNIT2=12,OMAXR $
TYPE PARM,,I,N,OTAPE2=0,OUNITX=-1 $
$+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
$  DESIGN OPTIMIZATION AND DYNAMIC SENSITIVITY
TYPE PARM,,I,N,DROPT $
$
$ ----------- PERFORM PHASE III OPERATIONS
$
EQUIVX   USET/USETX/-1 $
IF ( APP='NLST' ) EQUIVX   USETNL/USETX/-1 $
IF ( EXTRCV>0 ) PUTSYS(1,109) $
$  FORCE EXECUTION SO SDR1 IS NOT SKIPPED ON RESTART IN THE EVENT
$  THAT A NEW R.S. UG IS BEING LOCATED AND NO OTHER CHANGES ARE MADE.
PARAML   USETX//'USET'////S,N,NOUSET//'A'/S,N,NOASET/'Q'/S,N,NOQSET $
IF ( NOT(APP='STATICS' AND NOQSET=NOASET AND NOUSET>-1) AND
     FIXEDB>=0 ) THEN $ CHECK FOR R.S. SOLUTION VECTOR
   PARAML   UL//'TRAILER'/1/S,N,NCUL//S,N,NOUL $
$    USE UG FOR EXTERNAL TIP SUPERELEMENTS WHICH DO NOT NEED UL
   IF ( NOUL=-1 AND EXTRCV<>0 ) PARAML   UG//
                                'TRAILER'/1/S,N,NCUL//S,N,NOUL $
   IF ( NOUL<0 ) THEN $
      MESSAGE  //' DMAP FATAL MESSAGE 9058 (SUPER3) -'/
         ' THE SOLUTION FOR THE RESIDUAL STRUCTURE DOES NOT EXIST.' $
      EXIT $
   ENDIF $
ENDIF $ CHECK FOR R.S. SOLUTION VECTOR
$
PARAML   CASEUP//'TRAILER'/1/S,N,ICASE1//S,N,NOCASEUP $
EQUIVX   CASERS/CASEX/NOCASEUP $
IF ( NOCASEUP>-1 ) THEN $
   APPEND   CASEUP,CASERS/CASEX/1 $
   PARAML   CASERS//'TRAILER'/1/S,N,ICASE $
   PARAML   CASERS//'TRAILER'/3/S,N,MAXL $
   PARAML   CASERS//'TRAILER'/4/S,N,IPLT $
   PARAML   CASEUP//'TRAILER'/3/S,N,MAXL1 $
   PARAML   CASEUP//'TRAILER'/4/S,N,IPLT1 $
   ICASE=ICASE+ICASE1 $
   MAXL=MAX(MAXL,MAXL1) $
   IPLT=MAX(IPLT,IPLT1) $
   MODTRL   CASEX//ICASE/ICASE/MAXL/IPLT $
ENDIF $ NOCASEUP>-1
$
DBVIEW   UGF=UG   (WHERE SEID=* AND WILDCARD=TRUE) $
DBVIEW   PUGF=PUG  (WHERE SEID=* AND WILDCARD=TRUE) $
DBVIEW   QGF=QG   (WHERE SEID=* AND WILDCARD=TRUE) $
IF ( DROPT=5 | CNTL='ALL' $
SEP4     CASEX,PCDB,EMAP,XYCDB,UGF,PUGF,QGF/
         DRLIST/
         APP/'SEID'/S,N,NODRALL/S,N,SEID/S,N,NOUPL/CNTL $
$             NODRALL=-1 NO DATA RECOVERY REQUESTS
$             SEID   =-1 TO INDICATE TO SEDR FIRST TIME INTO LOOP
$
$    IF SOLS 101-159   THEN DROPT=0 (DEFAULT)
$       BUT IN SOLS 108, 111, OR 112 IF DYNSEN='YES'  THEN DROPT=2
$       AND IN SOLS 101, 103, OR 105 IF SENSITY=N     THEN DROPT=4
$    IF SOL  200 AND:
$       1. OPTIM='NO'   THEN DROPT=1
$       2. OPTIM='YES'  THEN DROPT=2
$       3. (NASPRT>-1 AND 1<OPTEXIT AND OPTEXIT<6) OR
$          MOD(DESITER1+1,NASPRT)=0 THEN DROPT=3
$
IF ( NODRALL<0 AND NOUPL<0 AND DROPT<=1 ) RETURN $
$
$ SET FOR ALL SUPERELEMENTS
SCRSPECX=LTOI(NOT(APP='REIG' AND SCRSPEC>=0)) $
$ DBC CONTROL PARAMETERS
DBCCONVX=DBCCONV $
ICYCLIC=LTOI(CYCLIC) $
IF ( POST=0 AND DROPT<>2 ) DBC,
         CASEX...................//'CASBCC'////////////////////
         -1/DBCPATH/S,N,CP/APP1/ICYCLIC/GEOMU/LOADU/POSTU/
         DBCDIAG/DBCCONV/DBCOVWRT/DESITER $
IF ( POST=-2 AND (OGEOM='YES' OR OGEOM=' ') ) GP1,
         GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL,/0/0/0 $
$
NOSE=LTOI(RSONLY) $
ENDDR = 0 $
DO WHILE (ENDDR >= 0) $ SUPERELEMENT DATA RECOVERY LOOP
$
   IF ( NODRALL=-1 AND DROPT>1 ) THEN $
$    IF DROPT>1 IS REQUESTED THEN
$    DO DATA RECOVERY FOR R.S., EVEN IF NO SUCH REQUESTS EXIST
      SEID=0 $
      PEID=0 $
      ENDDR=-1 $ DATA RECOVERY FOR SEID=0 ONLY
      EQUIVX   CASEX/CASEDR/ALWAYS $
      EQUIVX   UL/ULS/ALWAYS $
   ELSE $ NODRALL=-1 AND DROPT>1
      SEDRDR   DRLIST//
               S,N,ENDDR/S,N,SEID/S,N,PEID/S,N,SEDWN/S,N,NODR/NOSE $
      IF ( SEID<>0 ) THEN $ SET QUALIFIERS
         FSCOUP=FALSE $
         NLOOP=-1 $
      ENDIF $
      IF ( NODR>-1 ) THEN $
         IF ( DROPT>0 ) DELETE   /CASEDR,XYCDBDR,,,/ $
         PVT      PVTS,/PVTX/ $ UPDATE XPVT -- PVTX FORCES EXEC ON RESTA
$
$  INPUTS - UGD - FAMILY OF DOWNSTREAM DISPLACEMENT VECTORS - G-SIZE
$         - UL  - RESIDUAL STRUCTURE DISPLACEMENT VECTOR - A-SIZE
$
$  OUTPUT - ULS  - UPSTREAM BOUNDARY DISPLACEMENT VECTOR OF
$                  CURRENT SUPERELEMENT SEID - A-SIZE
$
         DBVIEW   MAPSF=  MAPS ( WHERE SEID=*      AND WILDCARD=TRUE ) $
         DBVIEW   UGD=  UG ( WHERE SEID=SEDWN AND WILDCARD=TRUE ) $
         DBVIEW   EQEXINSD=EQEXINS ( WHERE PEID=SEDWN ) $
         EXTRCV1=EXTRCV $
         IF ( SEDWN<>0 ) EXTRCV1=0 $
         DBVIEW   EMAPX=EMAP ( WHERE EXTRCV=EXTRCV1 ) $
         SEDR     EMAPX,CASEX,PCDB,DRLIST,XYCDB,SLT,ETT,
                  MAPSF,UGD,EQEXINSD/
                  ULS,CASEDR,PCDBDR,XYCDBDR/
                  APP/SEID/S,N,NOUP/S,N,NOSRT1//S,N,NOOUT/
                  S,N,NOPLOT/S,N,NOXYPLOT/'SEID'/NCUL $
         IF ( NOT(APP='STATICS' AND NOQSET=NOASET) AND
              NOGO=-1 AND FIXEDB>=0 AND SEID<>0 ) THEN $
            MESSAGE  //' DMAP INFORMATION MESSAGE 9012 (SUPER3) -'/
                       ' THE DISPLACEMENTS IN DOWNSTREAM SUPERELEMENT'/
                       SEDWN/' DO NOT EXIST.' $
            EXIT $
         ENDIF $ NOGO=-1 AND FIXEDB>=0
         IF ( SEID=0 ) EQUIVX   UL/ULS/ALWAYS $
      ENDIF $ NODR>-1
   ENDIF $  ELSE NODRALL=-1 AND DROPT>1
```

```
$
    IF ( NODR>-1 AND
         ( APP<>'REIG    ' OR NOT(SESEF=1 AND NOUP=-1) ) ) THEN $
$
      IF (HEATSTAT='YES') EQUIVX CASES/CASEDR/ALWAYS $
$
      CALL SETQ  CASES//SEID/PEID/S,MTEMP/S,K2GG/S,M2GG/S,B2GG/S,MPC/
                 S,SPC/S,LOAD/S,DEFORM/S,TEMPLD/S,P2G/S,DYRD/S,METH/
                 S,MFLUID $
$
      IF ( DROPT>0 ) THEN $
         DELETE   /UG,QG,OLB2,,/ $
         DELETE   /PUG,EGPSF,OUGV1,OPG1,OQG1/ $
         DELETE   /OEF1X,OES1X,OSTR1,OGS1,OUGV2/ $
         DELETE   /OPG2,OQG2,OEF2, OES2, OSTR2/ $
         DELETE   /OGS2,OES1M,OES1G,OSTR1M,OSTR1G/ $
         DELETE   /EGPSTR,ONRGY1,OGPFB1,,/ $
      ENDIF $
$
      EQUIVX   USET/USETX/-1 $
      IF ( APP='NLST' AND SEID=0 ) EQUIVX   USETNL/USETX/-1 $
      CALL PMLUSET  USETX//S,NOASET/S,NOBSET/S,NOCSET/S,NOGSET/S,NOLSET/
                    S,NOOSET/S,NOQSET/S,NORSET/S,NOSSET/S,NOTSET/
                    S,NOVSET/S,NOA/S,NOSET/S,NORC/S,NOMSET/
                    S,NOUSET $
$
      IF ( NOUSET=-1 ) THEN $
$ THIS CAN HAPPEN FOR PARAM,FIXEDB,-1 AND R.S. USET HAS NOT
$ BEEN GENERATED IN SEKR OPERATION
         PRTPARM  //4410/'DMAP'//SUBDMAP  $
      ELSE $ NOUSET=-1
         IF ( SEID<>0 ) NL99=0 $ RESET QUALIFIER IF NOT R.S.
$                              FOR PROPER MPTS IN NONLINEAR TRANSIENT
$
         PARAML   CASEDR//'DTI'/-1/35//S,N,SPCFOR $
$ IF SPCFORCES ARE REQUESTED THEN SPCFOR=-1, OTHERWISE 0
         PARAML   CASEDR//'DTI'/-1/167//S,N,GPFOR $
$ IF GPFORCES ARE REQUESTED THEN GPFOR=-1, OTHERWISE 0
         NOQG=LTOI(NOT(ORL(SPCFOR,GPFOR) OR (DROPT>1 AND DROPT<>4))) $
         PARAML   CASEDR//'DTI'/-1/170//S,N,ESE $
$ IF ESE ARE REQUESTED THEN ESE=-1, OTHERWISE 0
         GPFDR=(ORL(GPFOR,ESE)) $
$
         IF ( APP='CYC' AND APP1='STATICS ' ) THEN $
            CYCLIC1  CASEDR,GEOM3S,GEOM4S,DIT,/
                     DB1,GEOM3BK,DB3,DB4,DB5,CASEBK,BACK/
                     PM1/PM2/'STATICS'/PM4/PM5/PM6 $
            EQUIVX   CASEBK/CASEDR/ALWAYS $
            EQUIVX   GEOM3BK/GEOM3X/ALWAYS $
            MPYAD    FORE,BACK,/FB $
         ELSE IF ( CYCLIC AND (APP='REIG' OR APP='FREQRESP') ) THEN $
            EQUIVX   CASEBK1/CASEDR/ALWAYS $
         ELSE $ APP='CYC' AND APP1='STATICS '
            EQUIVX   GEOM3S/GEOM3X/ALWAYS $
         ENDIF $ APP='CYC' AND APP1='STATICS '
$
         IF ( APP='NLST' AND SEID=0 ) THEN $
$     CORRECTION FOR OLOAD OUTPUT - CRX IS ACTUALLY COMB IN NLSTATIC
            ADD      PG,PJ/DPJ//-1. $
            MPYAD    DPJ,CRX,/DPJX $
            ADD      PJR,DPJX/PJ1//-1. $
            EQUIVX   OL2/OLB2/ALWAYS $
         ELSE $
            CALL SEDISP  GOAT,GOAQ,LOO,KOO,LAO,POS,UOX,GPLS,USETX,SILS,
                         PJ,CASEDR,ULS,EDT,YS,GM,PSS,KFS,KSS,QR,CMPHO,OL2,
                         CMLAMA,CMPHA,PP1,PS1,MAR,MEA,XYCDBDR,CRX,
                         BACK,FB,QRG/
                         UG,QG,OLB2,ULS1,PJ1/
                         FIXEDB/NOQSET/NOTSET/IRES/APP/APP1/NOOSET/SEID/
                         NOOUT/CARDNO/PFILE/INREL/ALTRED/NORSET/NOQG/
                         NLHEAT/DROPT/NONLNR $
         ENDIF $
         IF ( SEID=0 ) EQUIVX   OLB2/OLBRS/ALWAYS $
         IF ( POST=0 AND (APP='REIG' OR APP='CEIGEN') AND
              DROPT<>2 ) DBC,
                    OLBRS.......................//
                    'LAMA'//////////////////////
                    -1/DBCPATH/S,N,CP/APP1/ICYCLIC/GEOMU/LOADU/POSTU/
                    DBCDIAG/DBCCONV/DBCOVWRT/DESITER $
$
         IF ( (NODRALL=-1 AND DROPT=4) OR DROPT=2 ) THEN $
$           IF SENSITY=N IS REQUESTED IN SOLS 101, 103, AND 105
$              AND NO DR REQUESTED THEN RETURN
$           IF PARAM,DYNSEN,YES IN SOLS 108, 111, AND 112 THEN RETURN
            RETURN $
         ELSE IF ( DROPT=5 ) THEN $
$           SUPERELEMENT SENSITIVITY - IGNORE DATA RECOVERY REQUESTS
            NOOUT=-1 $
         ENDIF $
$
         IF ( RSONLY ) EQUIVX   PCDB/PCDBDR/ALWAYS $
$ THIS IS NEEDED IF R.S.-ONLY MODEL AND NO SEPLOT OR
$ SEUPPLOT CARDS ARE PRESENT
$
         IF ( APP='STATICS ' AND NLHEAT ) THEN $
            TSET=GETSYS(TSET,10) $
            MATMOD   GEOM3S,GPLS,UG,,,/GEOM3SN,/18/TSET $
            GP3      GEOM3SN,EQEXINS,GEOM2S/SLTN,ETTN/123/123/123 $
            TA1      ,,ECTS,EPTS,BGPDTS,SILS,ETTN,CSTMS,/
                     ESTN,,GEIN,GPECTN,/
                     LUSET/123/123/1/123/123 $
         ELSE IF ( NONLNR AND SEID=0 ) THEN $
            EQUIVX   ESTL/ESTN/ALWAYS $
         ELSE $ APP='STATICS ' AND NLHEAT
            EQUIVX   EST/ESTN/ALWAYS $
         ENDIF $ ELSE APP='STATICS ' AND NLHEAT
$
         IF ( APP='STATICS' OR APP='REIG' OR APP='NLST' OR
            (APP='CYC' AND APP1='STATICS') ) NOCOMPX=NOCOMPS $
$
         RSPECTRX=LTOI(NOT(APP='TRANRESP' AND
                       RSPECTRA>=0 AND NOT(NONLNR))) $
$
$     WRITE END-OF-DATA IF CURRENT OUNIT2 IS DIFFERENT FROM
$        PREVIOUS OUNIT2 (OUNITX) AND THIS IS NOT THE
$        FIRST TIME THROUGH THE DATA RECOVERY LOOP.
         IF ( POST<0 AND OUNITX<>OUNIT2 AND
              OUNITX<>-1 ) OUTPUT2 //-9/OUNITX//OMAXR $
$     PUT LABEL ON CURRENT UNIT ONLY IF POST=-1
         IF ( POST=-1 AND OUNITX<>OUNIT2 ) OTAPE2=-1 $
$
         IF ( POST=-2 AND (OGEOM='YES' OR OGEOM=' ') ) THEN $
$     IF GEOMETRY DATA BLOCKS ARE REQUESTED THEN OUNIT1 AND
$           OUNIT2 ARE THE SAME UNIT.
            OUNIT1=OUNIT2 $
            OUTPUT2  CSTM,GPL,GPDT,EPT,MPT//0/OUNIT1//OMAXR $
            OUTPUT2  GEOM2,GEOM3,GEOM4,,//0/OUNIT1//OMAXR $
         ENDIF $ POST=-2 AND (OGEOM='YES' OR OGEOM=' ')
$
         IF ( POST=-1 AND OUGCORD=' ' ) OUGCORD='GLOBAL' $
         IF ( NOOUT>-1 ) THEN $
            CALL SEDRCVR,
                    UG,QG,BGPDTS,EQEXINS,CSTMS,CASEDR,MPTS,DIT,
                    ETT,OLB2,PJ1,ESTN,XYCDBDR,GEOM2S,GEOM3X,POSTCDB,
                    ECTS,GPLS,EPTS,SILS,INDTA,KELM,KDICT,GPECT,VELEM,
                    FORCE,XYCDB,PG,PCDBDR,USETX,SLT,UH,OL1,PP1,DLT,
                    FRL,SPSEL,DYNAMICS,CRX,QGE,OEFNLXX,OESNLXX/
                    MUGNI,PUG, OUGV1,OPG1,OQG1,OEF1X,OES1X,OSTR1,OGS1,
                    OUGV2,OPG2,OQG2,OEF2, OES2, OSTR2,OGS2,
                    OES1M,OES1G,OSTR1M,OSTR1G,EGPSTR,EGPSF,
                    ONRGY1,OGPFB1/
                    GRDPNT/APP/APP1/NOCOMPX/CURVPLOT/S,PFILE/NUMOUT1/
                    NUMOUT2/BIGER1/BIGER2/NUMOUT/BIGER/SRTOPT/LSTRN/
                    SRTELTYP/CURV/OUTOPT/OG/NINTPTS/S1M/S1G/S1AM/
                    S1AG/DOPT/TINY/NOELOF/NOELOP/TABS/SEID/S1/S,CARDNO/
                    PDRMSG/SCRSPECX/RSPECTRX/RSPRINT/TABID/INREL/GPFDR/
                    NLHEAT/AERO/ICYCLIC/FS/GEOMU/LOADU/POSTU/
                    DBCDIAG/DBCCONVX/POST/S,CP/DBCOVWRT/
                    S,OUNIT2/S,OTAPE2/OQG/OUG/OEF/OES/OEE/
                    OCMP/OGPS/OESE/OUMU/OGPF/OUGCORD/DESITER/RMSTRAIN/
                    BETA/LMODES $
$
            OUNITX=OUNIT2 $ SAVE UNIT NUMBER FOR COMPARISON ABOVE
         ENDIF $ NOOUT>-1
      ENDIF $ ELSE NOUSET=-1
   ENDIF $ NODR>-1 AND ( APP<>'REIG    ' OR NOT(SESEF=1 AND NOUP=-1)
ENDDO $  SUPERELEMENT DATA RECOVERY LOOP
$ WRITE END-OF-DATA ON FORTRAN UNIT OUNIT2
IF ( POST<0 ) OUTPUT2  //-9/OUNIT2//OMAXR $
$
SEID=-1 $ INITIALIZE
DO WHILE ( NOUPL>-1 AND ENDPLOT<>-1 ) $
$
$    PHASE IV - UPSTREAM DEFORMED PLOTS
$
   PLVCDR  EMAP,DRLIST//S,N,ENDPLOT/S,N,SEID/S,N,PEID $
   IF ( ENDPLOT<>-1 ) THEN $
      DBVIEW  SILSF     = SILS      (WHERE PEID=*) $
      DBVIEW  GPLSF     = GPLS      (WHERE PEID=*) $
$      COLLECT UPSTREAM DISPLACEMENT PLOT VECTORS
      PLTVEC  EMAP,DRLIST,PCDB,EQEXINX,SILX,SILSF,GPLSF,PUGF/
              PUGX,PCDBX/SEID/'SEID' $
      PARAML  PCDBX//'PRESENCE'////S,N,JPLOT $
      IF ( JPLOT>=0 ) THEN $
         PLTSET   PCDBX,EQEXINX,ECTX/PLTXY,PLTPARY,GPSETSY,ELTSETSY/
                  S,N,NSILS/S,N,JPLOT $
         PRTMSG   PLTXY//PDRMSG  $
         IF ( JPLOT>=0 ) THEN $
            PLOT     PLTPARY,GPSETSY,ELTSETSY,CASEX,BGPDTX,EQEXINX,
                     SILX,PUGX,PUGX,,/
                     PLOTY2/NSILS/0/JPLOT/-1/S,N,PFILE $
            PRTMSG   PLOTY2//PDRMSG $
         ENDIF $ JPLOT>=0
      ENDIF $ JPLOT>=0
   ENDIF $ ENDPLOT<>-1
ENDDO $  PHASE IV - UPSTREAM DEFORMED PLOTS
$
RETURN $
END $ SUPER3
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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
October 1993

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Nonlinear Random Response Prediction Using MSC/NASTRAN

5. FUNDING NUMBERS
WU 505-63-50-10

6. AUTHOR(S)
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NASA Langley Research Center
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
NASA TM-109029

11. SUPPLEMENTARY NOTES
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12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified — Unlimited
Subject Category — 71

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
An equivalent linearization technique has been incorporated into MSC/NASTRAN to predict the nonlinear random response of structures by means of Direct Matrix Abstract Programming (DMAP) modifications and inclusion of the nonlinear differential stiffness module inside the iteration loop. An iterative process was used to determine the rms displacements. Numerical results obtained for validation on simple plates and beams are in good agreement with existing solutions in both the linear and linearized regions. The versatility of the implementation will enable the analyst to determine the nonlinear random responses for complex structures under combined loads. The thermo-acoustic response of a hexagonal thermal protection system panel is used to highlight some of the features of the program.

14. SUBJECT TERMS
Nonlinear Dynamics; Random; Finite Element; MSC/NASTRAN; Equivalent Linearization

15. NUMBER OF PAGES
62

16. PRICE CODE
A04

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	